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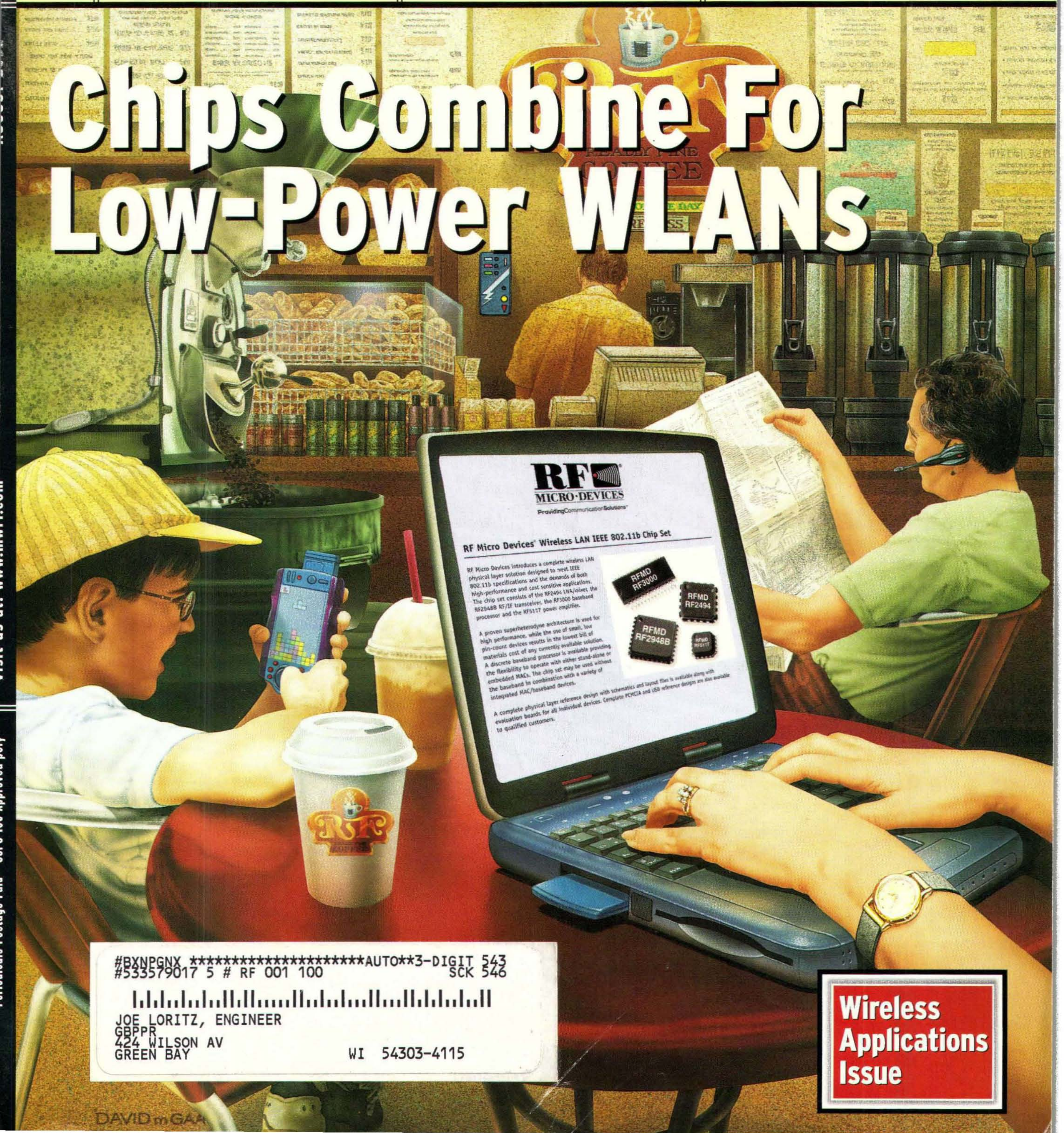
News
Wrapping up the 2002 MTT-S

Design Feature
Delving the depths of mHEMT technology

Product Technology
Synthesizers silence spurs and phase noise

Chips Combine For Low-Power WLANs



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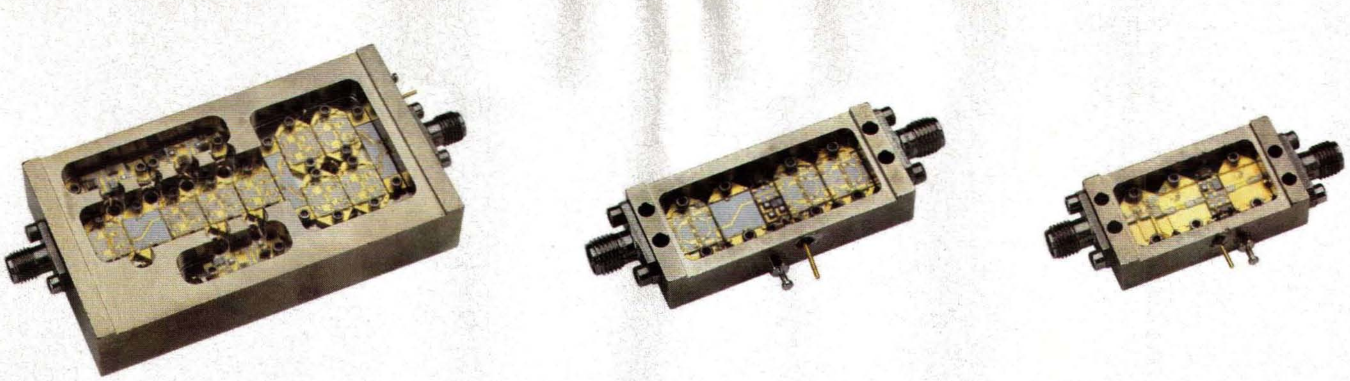
Wireless Applications Issue



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Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA018-203	0.5–18.0	20	5.0	2.5	7	17	2.0:1	250
JCA018-204	0.5–18.0	25	4.0	2.5	10	20	2.0:1	300
JCA218-506	2.0–18.0	35	5.0	2.5	15	25	2.0:1	400
JCA218-507	2.0–18.0	35	5.0	2.5	18	28	2.0:1	450
JCA218-407	2.0–18.0	30	5.0	2.5	21	31	2.0:1	500

Multi-octave amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA04-403	0.5–4.0	27	5.0	1.5	17	27	2.0:1	550
JCA08-417	0.5–8.0	32	4.5	1.5	17	27	2.0:1	550
JCA28-305	2.0–8.0	22	5.0	1.0	20	30	2.0:1	550
JCA212-603	2.0–12.0	32	5.0	3.0	14	24	2.0:1	550
JCA618-406	6.0–18.0	20	6.0	2.0	25	35	2.0:1	600
JCA618-507	6.0–18.0	25	6.0	2.0	27	37	2.0:1	800

Medium-power amplifiers

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-P01	1.35–1.85	35	4.0	1.0	33	41	2.0:1	1000
JCA34-P02	3.1–3.5	40	4.5	1.0	37	45	2.0:1	2200
JCA56-P01	5.9–6.4	30	5.0	1.0	34	42	2.0:1	1200
JCA812-P03	8.0–12.0	40	5.0	1.5	33	40	2.0:1	1700
JCA1218-P02	12.0–18.0	22	4.0	2.0	25	35	2.0:1	700

Low-noise octaveband LNAs

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-3001	1.0–2.0	40	0.8	1.0	10	20	2.0:1	200
JCA24-3001	2.0–4.0	32	1.2	1.0	10	20	2.0:1	200
JCA48-3001	4.0–8.0	40	1.3	1.0	10	20	2.0:1	200
JCA812-3001	8.0–12.0	32	1.8	1.0	10	20	2.0:1	200
JCA1218-800	12.0–18.0	45	2.0	1.0	10	20	2.0:1	250

Narrowband LNAs

Model	Freq. Range GHz	Gain dB min	N/F dB max	Flatness +/–dB	1 dB Comp. pt. dBm min	3rd Order ICP typ	VSWR In/Out max	DC Current mA
JCA12-1000	1.2–1.6	25	0.75	0.5	10	20	2.0:1	80
JCA23-302	2.2–2.3	30	0.8	0.5	10	20	2.0:1	80
JCA34-301	3.7–4.2	30	1.0	0.5	10	20	2.0:1	90
JCA56-401	5.4–5.9	40	1.0	0.5	10	20	2.0:1	120
JCA78-300	7.25–7.75	27	1.2	0.5	13	23	2.0:1	120
JCA910-3000	9.0–9.5	25	1.3	0.5	13	23	1.5:1	150
JCA910-3001	9.5–10.0	25	1.4	0.5	13	23	1.5:1	150
JCA1112-3000	11.7–12.2	27	1.4	0.5	13	23	1.5:1	150
JCA1213-3001	12.2–12.7	25	1.4	0.5	10	20	2.0:1	200
JCA1415-3001	14.4–15.4	35	1.6	1.0	14	24	2.0:1	200
JCA1819-3001	18.1–18.6	25	2.0	0.5	10	20	2.0:1	200
JCA2021-3001	20.2–21.2	25	2.5	0.5	10	20	2.0:1	200

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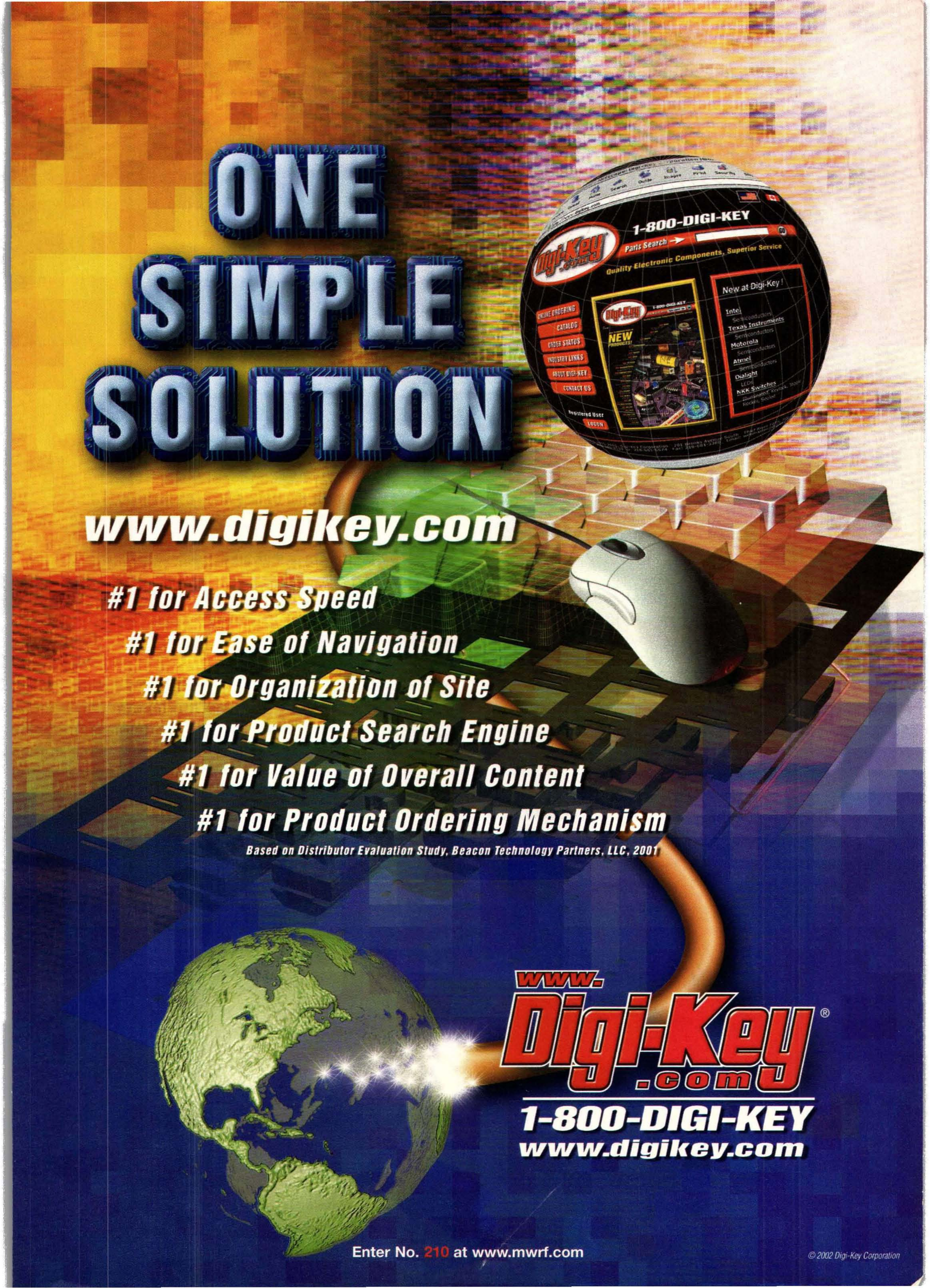
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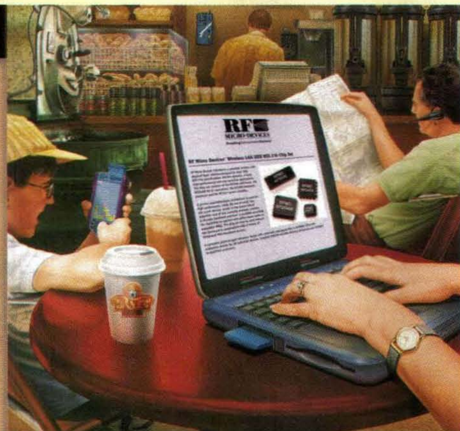

COVER STORY

102 Chip Set Offers Compact 2.4-GHz WLAN Solution

This four-piece IC set blends semiconductor processes to achieve the smallest, lowest-power solution for developers of IEEE 802.11b WLAN products.

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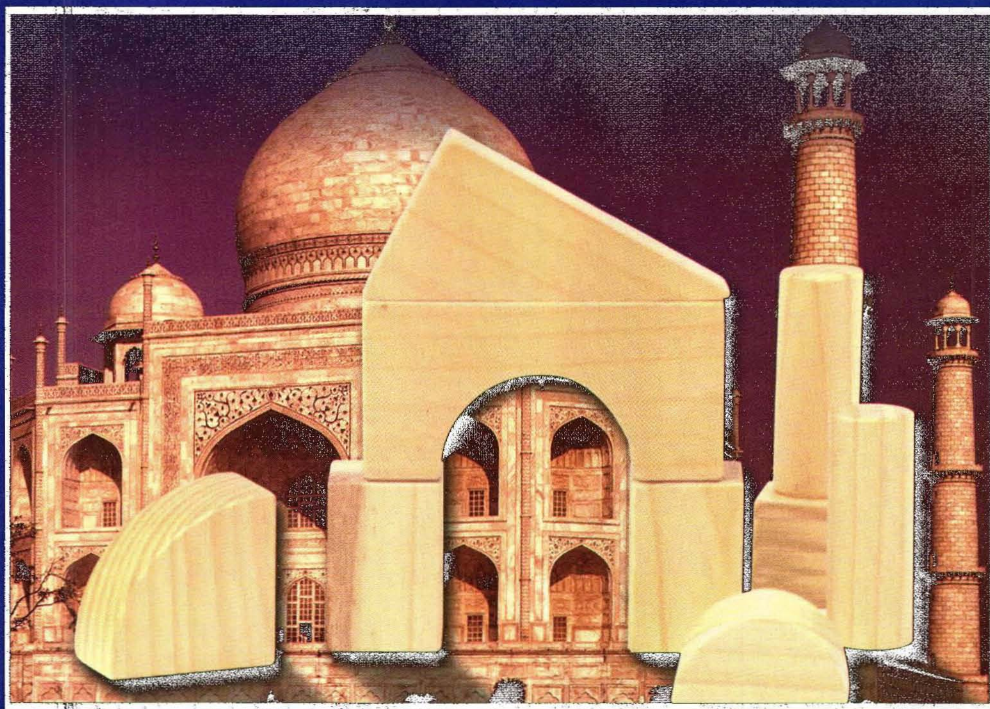

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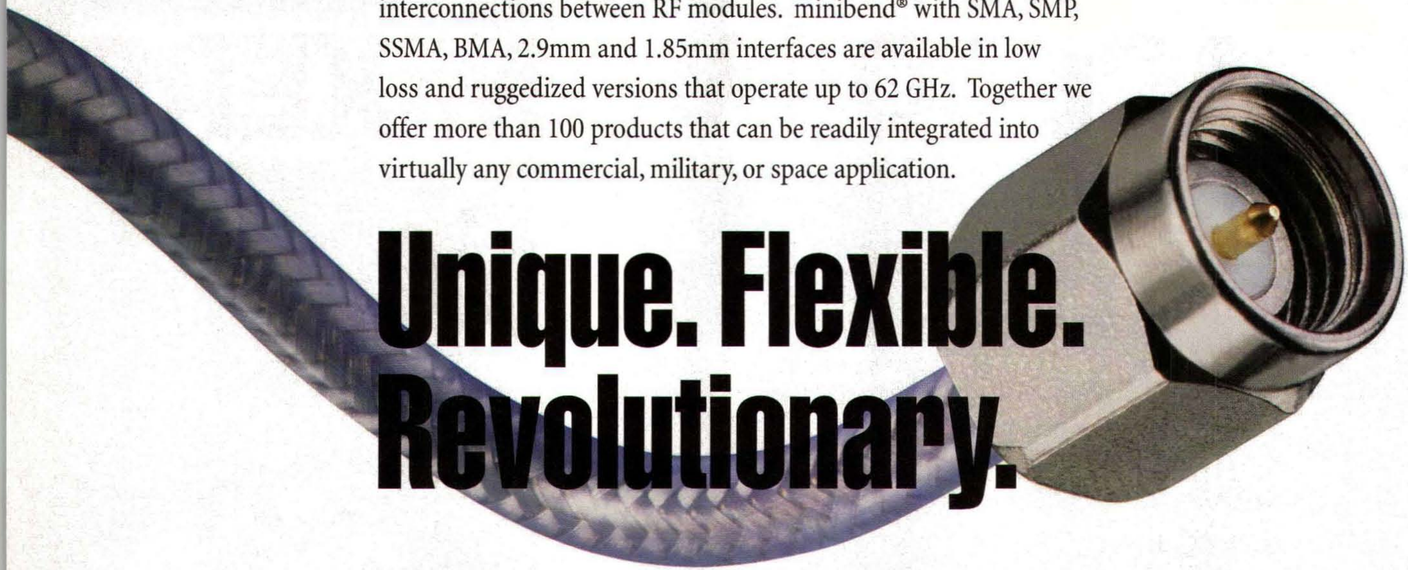

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Where Are The Mentors?

▶▶IF YOU EVER HAVE HAD the privilege of being a mentor to someone during your career, it is quite likely that you found it rewarding and essential for developing engineers at your company. But how important a role does mentoring play in the RF and microwave engineering world of today? I wish to examine this in light of my experiences in the industry.

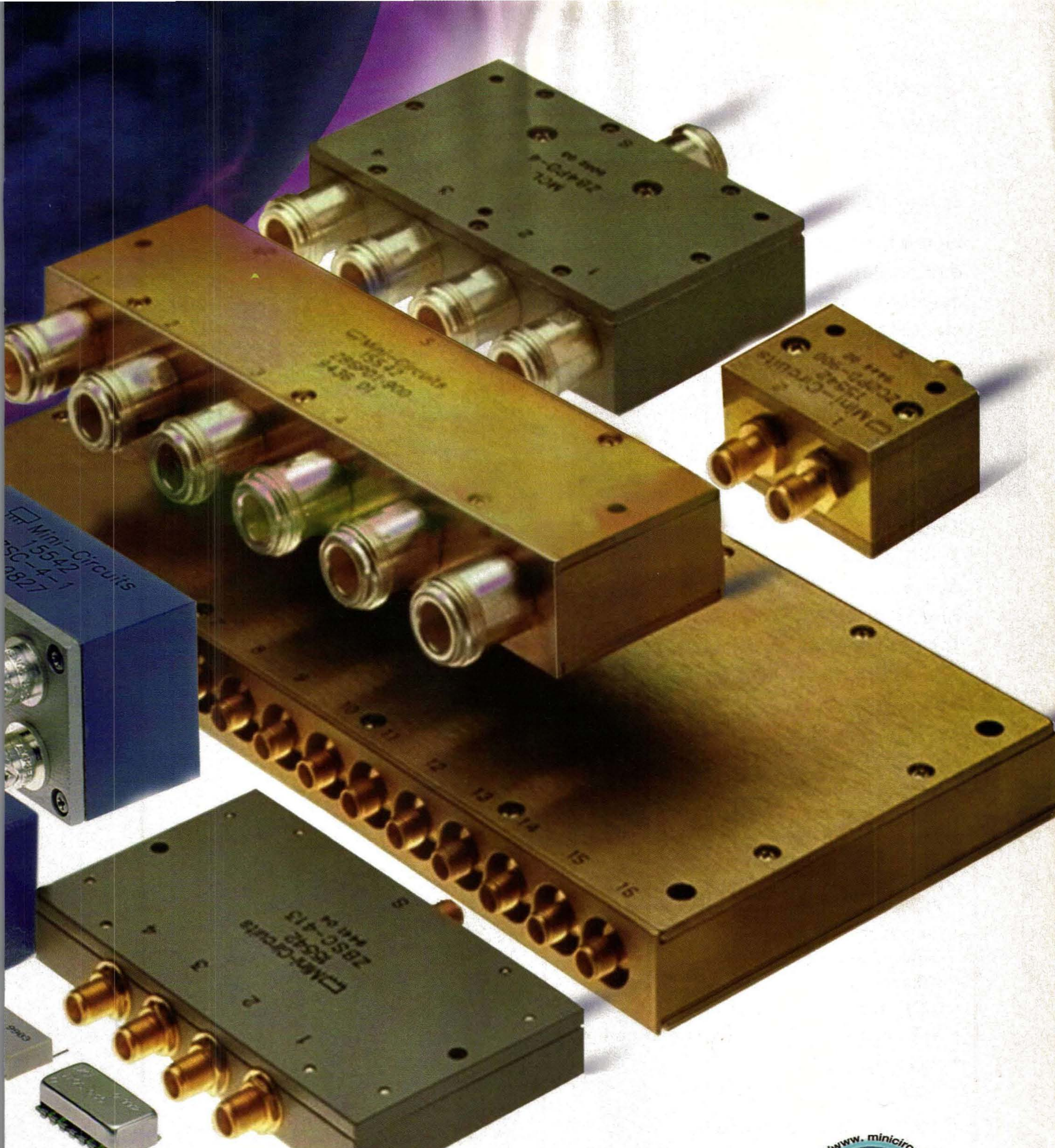
I have worked in the wireless business for approximately 13 years. I may have had a true mentor for perhaps my first two years in the business. As you gain experience in your field, you are expected to take on more responsibilities and to figure things out for yourself. This is a reasonable expectation. Still, how is the average engineer supposed to learn and advance in today's RF/Microwave industry without the influence of older engineers supporting and encouraging the younger ones? For the past six years, I have been assigned a few projects that have been quite demanding. Neither the resources nor the training were available within the company. There have been many questions, but few answers. Fortunately, engineers from other companies still enjoy sharing their knowledge with others whom they do not even know.

In these trying economic times, the firms that are able to recruit want someone who comes in and makes an immediate difference. There is little or no formal training or mentoring. Many senior-level engineers sit in offices, write documents, and attend numerous meetings. But where are the engineers who still work on the bench, helping young engineers to solve problems? (Has the bench lost its appeal, or become second-class engineering?) With cycle times decreasing and system complexity increasing, where does even the experienced engineer go for help, if more senior engineers no longer apparently have the time—or desire—to help you think through your problems? Many of the senior engineers have been off of the bench for so long that they are not able to give you the help that you may need.

How can a company possibly remain successful unless they are actively encouraging senior and principal staff engineers to interact with other staff engineers? It seems so different today compared to years past. The market is slipping, the passion appears to be waning, the ship is starting to steer off course, and I believe a generation gap has formed.

I used to enjoy this field. There was a certain team spirit and willingness to see that the department and company do well. It appears that many engineers are looking out for themselves these days.

John David
Company name withheld



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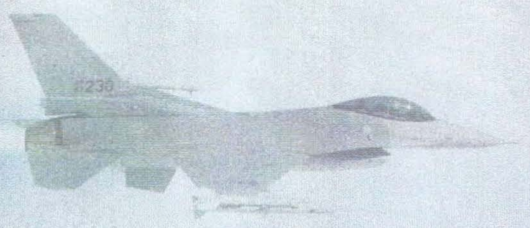

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Helping To Train Future Engineers

Education is essential to the continuation of the high-frequency industry. Yet, the continuing education of their engineering employees is often taken for granted by many otherwise sophisticated firms. While far too few establish in-house training programs or affiliations with local universities, many leave their engineers to fend for themselves when it comes to being up to date with technology and design methods.

Mentoring has traditionally been an important element in the education of newer employees and a key component in a well-organized company's long-term planning.

In this month's "Feedback" column (see p. 13), one passionate reader (whose name and affiliation have been withheld to protect the innocent) bemoans the lack of formalized mentoring at many companies and the challenges faced by many new engineers in having to handle complex projects with little or no guidance. The reader points to the need for more interactions between older, more experienced engineers and younger engineers in need of training.

Yet, in these challenging economic times, many companies are concerned with their quarter-to-quarter results and do not consider the importance of long-term planning. Mentoring has traditionally been an important element in the education of newer employees and a key component in a well-organized company's long-term planning. Mentoring has also been a way to pass along those "little secrets," the special test techniques and design approaches that have been learned through trial and error. All too often, modern businesses want to hire an engineer who will have an immediate impact on their general ledger, but are unwilling to involve the time of a second engineer as a mentor.

Industry trade shows will never replace a good mentoring program, but they are also meant as an important component in the education of the modern engineer. Trade shows such as the Wireless Systems Conference and Exhibition and the recent Microwave Theory & Techniques Symposium (MTT-S, see p. 33 for a wrapup) provide good technical presentations on focused topics, with a chance for interaction with other engineers. The upcoming Military Electronics Show, scheduled for September 24-25, 2002 in the Baltimore Convention Center, is another trade show to add to that list, especially for engineers involved in the military side of the business (please visit www.mes2002.com for more information).

A formal mentoring program is still one of the best ways to pass along the knowledge of experience. But engineers enjoy helping each other with problems, and a trade show such as the Military Electronics Show also serves as an important classroom, giving engineers a chance to compare notes.

Jack Browne

Publisher/Editor

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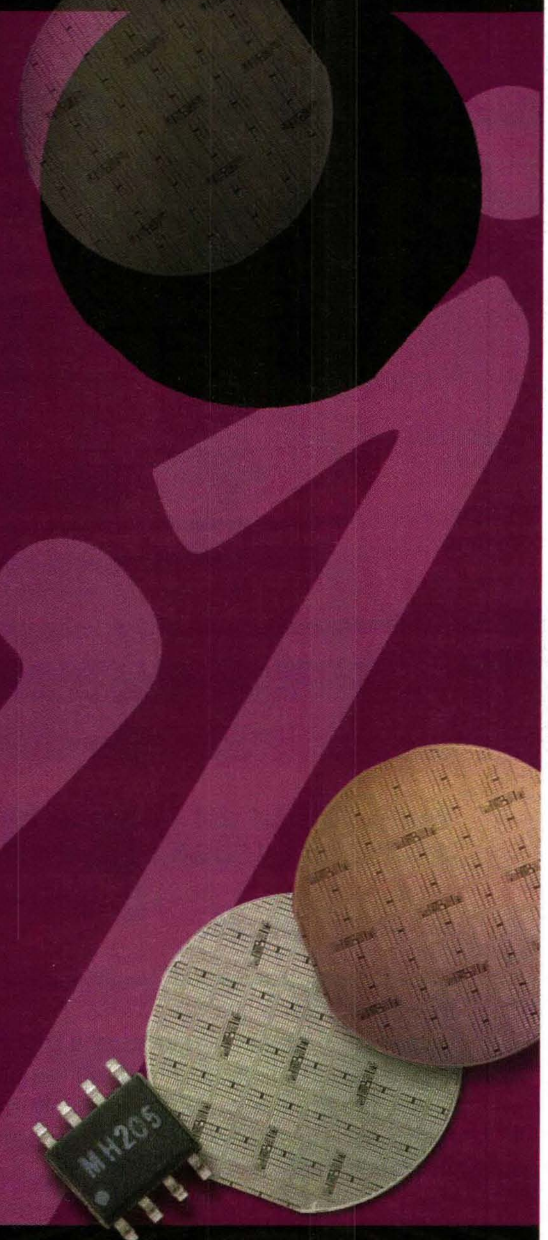

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MH202	17 dBm	890-960	640-760	200-250	8.5 dB	+30 dBm	45 dB
MH203	17 dBm	800-960	1100-1310	200-350	8.5 dB	+32 dBm	45 dB
MH205	17 dBm	800-915	700-845	70-120	8.5 dB	+32 dBm	45 dB

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the front end

News items from the communications arena.

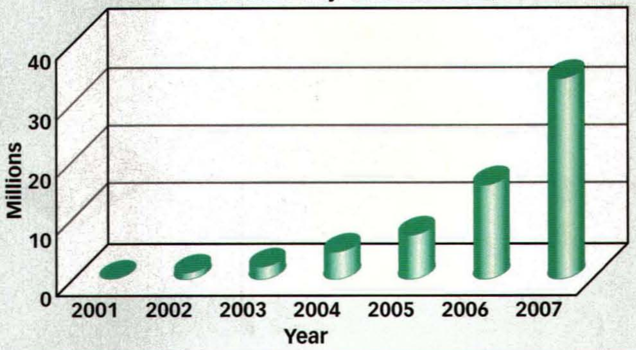
Fragmentation Of The US Digital Radio Market Will Continue

OYSTER BAY, NY—The newly formed US digital radio market already stands divided between two separate satellite broadcasting standards. According to the findings in "Satellite Radio: Global Markets for In-Vehicle Satellite and Terrestrial Digital Radio," a report from Allied Business Intelligence, Inc. (ABI), the lines of demarcation will only grow when terrestrial digital radio makes its debut.

The amplitude-modulation/frequency-modulation (AM/FM) broadcasting community will soon make its move into the digital domain, with help from iBiquity's In-Band On-Channel (IBOC) technology. In 2003, IBOC-ready receivers (Rxs) are slated to reach the US automotive original-equipment-manufacturer (OEM) and aftermarkets.

The average new car buyer will soon face a considerable amount of new and confusing choices for in-vehicle radio Rxs. According to the report's findings, domestic shipments of digital radio Rxs will increase from approximately 650,000 units in 2002 to more than 33 million in 2007 **(see figure)**.

Shipments of digital radio receivers, US market: 2001 to 2007 (Source: Allied Business Intelligence, Inc. From the study: Satellite Radio)



In light of Ford and GM's restructuring, digital radio promises to be a suitable channel to deliver extremely low-cost telematics data services to a new audience, whom OnStar has had little to no success reaching. A downlink such as terrestrial digital radio would complement the satellite radio data pipe and provide additional flexibility to not only the telematics service provider (TSP), but to the customer as well and at a much lower price point.

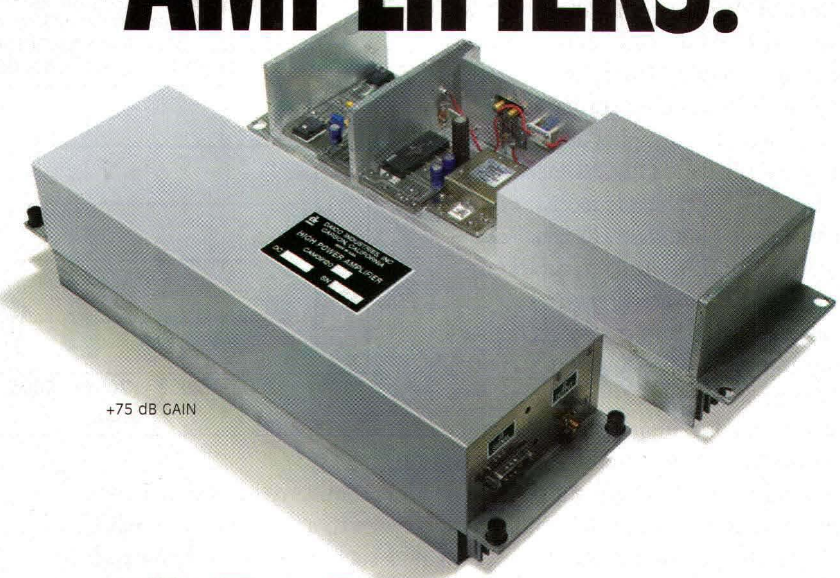
Corporate VoIP Revenue Will Reach $2.46B In Europe By 2007

CAMBRIDGE, ENGLAND—According to "IP Voice Services: European corporate market forecasts 2002-2007," a report from Analysys Research, Voice over Internet Protocol (VoIP) is already being used to carry an estimated 6 percent of international traffic on routes where competition is limited. The next big potential market is corporate IP voice, which could account for at least 15 percent of overall business voice revenues by 2007. In the long run, VoIP is expected to prove to be cheaper for capital and operational expenditure.

Corporate users are turning to VoIP as a means of simplifying their networks and reducing call and operational costs. At the moment, the most attractive situation in which to deploy a VoIP system is to connect small sites where a private branch exchange (PBX) is not justified or as an add-on to an existing system that has run out of capacity. In the future, VoIP-based virtual private networks (VPNs) are likely to have wide appeal for corporate customers as a way of achieving flexible use of the access bandwidth and saving on overall VPN costs.

Corporate VPN revenues are expected to reach at least EUR2.5 billion (approximately $2.46 billion US) in 2007. They could be as much as EUR7.4 billion (approximately $7.3 billion US), if the benefits of VoIP are demonstrated. The revenue stream will be dominated by VoIP VPN off-net calls, because the principal attraction of installing a VPN for the customer is the large discounts on internal calls that can be achieved even between distant or international sites.

APOLOGIES TO OUR COMPETITION. WE ARE NOW DELIVERING CUSTOM HIGH-POWER AMPLIFIERS.



+64 dBm (pulsed)

We've raised the bar again. Applying 35 years of build-to-spec design experience and adding to our already successful line of control products, next comes our pulsed power amplifiers for weather radar and Defense Systems… accomplished through our elegant modular design approach.

Our amplifiers provide a new standard in power, efficiency, quality and reliability in the UHF range. They include power output monitoring, precision phase adjustability and temperature control, to perform in a variety of rugged applications. Moreover, our modular design supports manufacturability, repeatability and serviceability.

Stay ahead of your competition and call us for your next custom high-power amplifier. We'll help make your products leaders in their field.

ELECTRICAL SPECIFICATIONS

Parameter	Min	Typ	Max	Unit	Notes
Frequency	430		470	MHz	50% in band
Small Signal Gain	75		80	dB	
VSWR In/Out			1:2:1		
P1 dB Comp.	63.5	64.0		dBm	
Harmonics Out II, III	60	65		dBc	
Gain Tracking		±0.2	±0.3	dB	Unit-to-unit
Phase Tracking		±2.0	±3.0	degree	Unit-to-unit
VSWR Withstand Under Full Power			∞:1		All phases
Efficiency	52	57		%	
Duty Cycle			15	%	

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NASA Space Act Agreement Formalizes Cooperation

HANCOCK COUNTY, MS—Drawing on the expertise of engineers and scientists, NASA, the National Imagery and Mapping Agency (NIMA) and the United States Geological Survey (USGS) have assembled the Joint Agency Commercial Imagery Evaluation (JACIE) team for government assessment of commercial remote sensing data for national applications. The JACIE team formalized its partnership through an interagency Space Act Agreement, which was signed on June 25 by the three participating government agencies.

NASA initiated a Scientific Data Purchase project in 1997 to evaluate an approach for purchasing commercial remote-sensing data sets for Earth science research and applications. Stennis Space Center's Earth Science Applications Directorate manages the Scientific Data Purchase project and verifies and validates the commercial data sets delivered to NASA. Remote sensing, the observation of the Earth from a vantage point in space or from an aircraft, produces measurements that may be analyzed for important information about the Earth, including environmental monitoring and natural-resource management. In an effort to expand and accelerate the use of remote-sensing capabilities offered by the commercial sector, NASA and NIMA have established data-purchasing programs—the practice of purchasing commercial remote-sensing data sets. USGS may soon follow in the practice.

"In compliance with the Commercial Space Act of 1998, NASA buys data to support Earth science research and applications," said Vicki Zanoni, verification and validation projects manager for the Earth Science Applications Directorate at Stennis Space Center. "To ensure that the purchased data is accurate and useful to the science community, NASA independently characterizes the performance of the data. JACIE was formed to leverage several agencies' capabilities to jointly characterize commercial data and provide a unified government assessment in interfacing with industry."

"NASA independently characterizes the performance of the data."

Collaboration Results In Complete Bluetooth Solution

AMSTERDAM, THE NETHERLANDS—RF Micro Devices, Inc. (RFMD) and Brightcom Technologies Ltd. have announced a collaboration to offer a complete Bluetooth™ solution. The Bluetooth solution is comprised of RFMD's RF2968 transceiver and BrightCom's IntelliBLUE™ chips and BrightCORE™ software. RFMD and BrightCom intend to offer evaluation platforms and reference designs, giving customers the ability to rapidly develop Bluetooth-enabled applications and quickly move into volume manufacturing. RFMD and BrightCom held live demonstrations of the combined solution at their respective booths at Bluetooth Congress 2002, which was held June 12 to 14.

The two companies are cooperating to capitalize on each other's core strengths. RFMD is a provider of RF communications solutions for an array of wireless applications and products. BrightCom is focused on Bluetooth system-on-a-chip (SoC) solutions, including baseband, protocol stacks, profiles, and BrightAPIs™ for real applications.

A.J. Nadler, director of Silicon Systems at RFMD, commented, "Given our combined strengths and specialization in wireless technology and integrated-circuit design, we expect our complete solution will be uniquely valuable to manufacturers seeking highly integrated, high-performance, and cost-effective Bluetooth solutions."

RFMD's RF2968 transceiver is a compact 5 × 5-mm solution with a low external component count. The RF2968 uses a high-performance bipolar-complementary-metal-oxide-semiconductor (BiCMOS) process technology, resulting in superior RF characteristics and a high level of integration, including the voltage-controlled oscillator (VCO) and intermediate-frequency (IF) filter, and eliminates the need for external Baluns or T/R switch. The transceiver features self-calibration, which reduces test time and cost, as well as improves yields.

BrightCom's IntelliBLUE application processors provide a fast and easy way to implement Bluetooth technology in a wide range of residential, industrial, and commercial wireless applications. This highly integrated solution reduces the bill of materials for the overall Bluetooth-enabled system and does not require any change in a customer's existing hardware or operating systems. A single chip includes the application processor integrated circuit (IC) with all baseband functionality, software drivers for universal asynchronous receiver-transmitter (UART), pulse-code modulation (PCM)/CVSD, universal-serial-bus (USB) host and device, the complete Bluetooth protocol stack, and the BrightAPI with Bluetooth profile support.

Internet-Based Solutions Suite For Telcos Is Introduced

ATLANTA, GA—Fujitsu Consulting, an organization involved in management and technology consulting, has announced the launch of its Enhanced Internet Protocol (IP) Services Solution, a business-driven technology architecture designed to meet the growing demand for converging voice, video, and data onto one efficient platform to boost company competitiveness and customer service.

The Enhanced IP Services Solution is the first of three planned offerings comprising the TELCOM360 solutions suite that is being demonstrated live at SuperComm, the annual communications and IT conference and exhibition.

"We have a 360-degree view of the communications industry."

"Fujitsu Consulting creates unique business solutions to address each customer's individual challenges and requirements. The common element is the convergence of business processes, information technologies, and networks to create a focused advantage. The end results are solutions that are tailored to deliver optimal results that create new business value and opportunities, while enhancing customer efficiency and profitability," said Bob Manning, president of telecommunications solutions at Fujitsu Consulting. "We have a 360-degree view of the communications industry and have evolved our technology and service offerings to stay at the forefront of market changes."

Kudos

RYDE, ISLE OF WIGHT, ENGLAND—Pascall Electronics, a member of the Intelek group of companies, celebrated its twenty-fifth birthday on May 31.

Pascall now employs 130 staff members in a purpose-built 35,000-sq.-ft. facility. The company designs and manufactures specialist power supplies for in-flight entertainment systems, defense and communication applications, satellite carrier monitoring equipment, and RF components and subsystems.

Pascall was founded in 1977 as an importer of high-tech electronic components, mainly from the US. As the business developed, Pascall built up a team of RF and power-supply engineers to design their own products. Pascall's first manufacturing facility opened on the Isle of Wight in 1980. The firm moved to its current location in Ryde in 1999.

MYRTLE BEACH, SC—AVX Corp., an international supplier of electronic components, has received the *Corporate Technical Achievement Award (CTAA)* from The American Ceramic Society, an organization dedicated to the advancement of ceramics. The award was formally presented to AVX at the 2002 Annual Meeting, which was held recently in St. Louis, MO.

The CTAA was initiated in 1986 to recognize outstanding technical achievements in the field of ceramics made by The American Ceramic Society corporate members. These accomplishments must show significant technical merit and represent a gain to society through the commercialization of ceramic technology.

VISTA, CA—Palomar Technologies, a manufacturer of automated assembly systems and services for broadband communications, announced that it has received ISO 9001 Certification. The certification applies to all phases of Palomar's quality-management system, including planning, design, manufacture, sales, service, and customer satisfaction.

SUNNYVALE, CA—Sirenza Microdevices, a designer and supplier of RF components for communications equipment manufacturers, announced that it has been awarded US patent number 6,373,346, entitled "Laser Driver Pre-emphasis and De-emphasis Method and/or Architecture with Tuning and Duty Cycle Control."

The newly issued patent discloses a unique analog method for preshaping data in order to improve the signal-to-noise ratio (SNR) of vertical-cavity-side-emitting-laser (VCSEL)-based fiber-optic transmitters (Txs). This technique is being applied to Sirenza Microdevices products developed for 10-Gb Ethernet systems.

SAN DIEGO, CA—StratEdge, a firm that is involved in the design and production of ceramic packages for high-speed wireless components, announced that it has received a Republic of China patent, Number NI-118360, for its High Frequency Passband Microelectronics Package. This Low Cost Commercial (LCC) family of DC-to-23-GHz ceramic packages provides an interconnect system that ensures electrical integrity, mechanical protection, and thermal control in the harshest environments, for high-frequency gallium-arsenide (GaAs) monolithic-microwave-integrated-circuit (MMIC) devices used for C- and Ku-band very-small-aperture-terminal (VSAT) applications. MRF

OMNIYIG DESIGNS TECHNOLOGY

Since 1973 OMNIYIG has been at the forefront of advanced YIG technology, manufacturing state-of-the-art YIG components, Detectors, Limiters, Comb Generators, and integrated subsystems. We are continually designing and manufacturing new state-of-the-art YIG components for Airborne Systems/Space/Ship Board Commercial/EW/ECM/Jammers/Radar/Communication.

OMNIYIG's products are available for commercial use, yet are built under stringent military specifications (MIL-E-5400) Class II/MIL-STD-883 (Typ). Our advanced products are designed into some of the world's most sophisticated systems, including commercial, EW, and ECM programs such as the ALQ-99, ALQ-117, ALR-172, ALR-56C, ALR-62, ALR-64, ALR-67, ALR-69, APR-39, WLR-8, Rapport III and we are on board the F-15, F-16, F-18, EA6B, EF111, B-1, B2 Stealth, L-130 and more. We maintain and continue technology improvement.

YIG BAND REJECT FILTERS

- Frequency Range: 0.4 GHz to 26 GHz
- Octave and Multioctave Frequency Ranges
- Sizes: 1.2 x 1.2 x 1.2 inch
  1.0 x 1.4 x 1.4 inch
  1.4 x 1.4 x 1.4 inch
  1.7 x 1.7 x 1.7 inch

YIG MULTIPLIERS

- Frequency Range: 0.4 GHz to 26 GHz
- Octave and Multioctave Frequency Ranges
- Input Frequency: 100 MHz to 2000 MHz; fixed or variable
- Output Frequency: 100 MHz to 26 GHz
- Sizes: 1.4 x 1.4 x 1.4 inch
  1.7 x 1.7 x 1.7 inch

YIG OSCILLATORS

- Frequency Range: 0.4 GHz to 20 GHz
- Octave and Multioctave Frequency Ranges
- Sizes: 0.5 x 1.0 x 1.0 inch
  1.7 x 1.7 x 1.7 inch
  1.7 x 1.5 inch round

DRIVERS are available as integrated components with the YIG devices. Analog drivers with 0–10 volts and 12-bit digital drivers.

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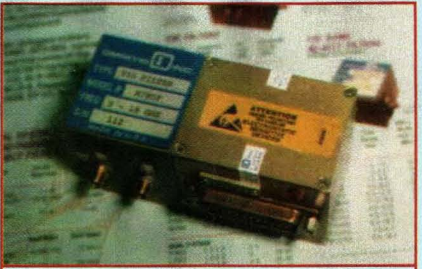

YIG BAND REJECT FILTERS

Omniyig Model No.	Freq. Range (GHz)	Ins. Loss (max.) (dB)	Bandwidth @ 40 dB (min.) (MHz)
6- and 8-STAGE			
P106RX	0.5 – 1.0	1.5	10
L106RX	1.0 – 2.0	1.5	10
C106RX	4.0 – 8.0	1.5	20
X106RX	8.0 – 12.4	1.5	20
Ku106RX	12.0 – 18.0	1.8	20
M102RX	4.0 – 12.4	1.5	8
M103RX	4.0 – 12.4	1.5	10
M107RX	8.0 – 18.0	1.5	20

YIG OSCILLATORS

Phase Noise: 120 dBc/100 Khz

Omniyig Model No.	Freq. Range (GHz)	RF Pwr. Output (mW)	2nd Har. (dBc)
YOM149	0.5 – 2.0	20–60	16
YOM1518	1.0 – 4.0	20–60	16
YOM83	2.0 – 6.0	20	12
YOM1948	3.5 – 10.5	15	12
YOM1317	2.0 – 8.0	20	12
YOM818	8.0 – 18.0	20	12
YOM1516	6.0 – 18.0	20	10
YOM2320	2.0 – 10.0	13	11

We offer other models with 2nd Harmonic –60 dBc. Oscillators integrated with 2-stage filters are available.

YIG MULTIPLIERS

STANDARD UNITS

Output Computer Tested

Omniyig Model No.	Input Freq.	Output (GHz)	Output Pwr. (dBm)
YM 1027	100 MHz	1 – 18	–40
YM 1028	200 MHz	1 – 18	–30
YM 1029	500 MHz	1 – 18	–22
YM 1087	.1 – .2 GHz	1 – 12	–25

* RF input power on all models 0.7 to 1.0 watts.

Other designs are available.

Fast switching, MIL-Spec Hi-Reliability and units integrated with drivers, oscillators or amplifiers also available.

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THIN FILM YIG OSCILLATORS

Omniyig Model No.	Freq. Range (GHz)	RF Pwr. Output (mW)	2nd Har. (dBc)
YOM1517	0.5 – 2.0	20–60	16
YOM1518	1.0 – 4.0	20–60	16
YOM1514	4.0 – 12.0	10	15
YOM1513	4.0 – 10.0	10	15
YOM83	2.0 – 6.0	20	12
YOM1948	3.5 – 10.5	15	12
YOM1317	2.0 – 8.0	20	12
YOM818	8.0 – 18.0	20	12
YOM1516	6.0 – 18.0	20	10
YOM2320	2.0 – 10.0	13	11
YOM2321	5.0 – 18.0	13	9

YIG OSCILLATORS with PERMANENT MAGNET

Omniyig Model No.	Freq. Range (GHz)	RF Pwr. Output (mW)	2nd Har. (dBc)
YOM2776	0.5 – 2.0	20	12
YOM277	2.0 – 4.0	20	12
YOM2778	4.0 – 8.0	20	12
YOM2779	2.0 – 8.0	20	-120
YOM2780	8.0 – 12.0	20	-120
YOM2781	12.0 – 18.0	20	-110

YIG MULTIPLIERS

STANDARD UNITS

Output Computer Tested

Omniyig Model No.	Input Freq.	Output (GHz)	Output Pwr. (dBm)
YM 1001	1–2 GHz	2 – 13	6
YM 1002	100 MHz	1 – 12	–33
YM 1003	200 MHz	1 – 12	–28
YM 1004	500 MHz	1 – 12	–10
YM 1026	1–2 GHz	2 – 18	2
YM 1027	100 MHz	1 – 18	–40
YM 1028	200 MHz	1 – 18	–30
YM 1029	500 MHz	1 – 18	–22
YM 1087	.1 – .2 GHz	1 – 12	–25

* RF input power on all models 0.5 to 1.0 watts.

Fast switching, MIL-Spec Hi-Reliability and units integrated with drivers, oscillators or amplifiers also available.

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YIG FILTERS

Omniyig Model No.	Freq. Range (GHz)	Ins. Loss (dB)	Bandwidth @ 3 dB (MHz)
6-STAGE			
P106	0.5 - 1.0	6.5	12-30
L106	1.0 - 2.0	5.5	20-35
S106	2.0 - 4.0	5.0	20-40
C106	4.0 - 8.0	4.5	25-40
X106	8.0-12.4	4.5	25-40
Ku106	12.4-18.0	4.5	28-45
3-STAGE			
P103	0.5 - 1.0	5.0	14-25
L103	1.0 - 2.0	3.5	20-35
S103	2.0 - 4.0	3.0	20-35
C103	4.0 - 8.0	3.0	25-40
X103	8.0-12.4	3.0	25-40
Ku103	12.4-18.0	3.5	30-45
4-STAGE			
P104	0.5 - 1.0	6.0	12-23
L104	1.0 - 2.0	4.5	20-35
S104	2.0 - 4.0	4.0	20-35
C104	4.0 - 8.0	4.0	25-40
X104	8.0-12.4	4.0	25-40
Ku104	12.4-18.0	4.0	28-45
DUAL 2-STAGE			
P1022	0.5 - 1.0	3.5	17-30
L1022	1.0 - 2.0	3.0	24-35
S1022	2.0 - 4.0	2.5	25-40
C1022	4.0 - 8.0	2.5	25-40
X1022	8.0-12.4	2.5	25-40
Ku1022	12.4-18.0	2.5	30-45
MULTIOCTAVE BANDS			
M1611/2	1.0 - 18.0	5.5	25-65
M1612/4	2.0 - 18.0	6.5	25-75
M102/2[5]	1.0 - 12.4	5.0	25-60
M1613/2	1.0 - 12.4	5.5	25-60
M1048/4	4.0 - 18.0	6.0	25-60
M203/4[5]	1.0 - 18.0	6.5	25-70

Other Multioctave YIG Filters are available. Analog and 12-bit digital drivers are available for all YIG devices.

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OMNIYIG INC.

DETECTORS, COMB GENERATORS and YIG FILTERS/ OSCILLATORS

ZERO BIAS SCHOTTKY DETECTORS

Omniyig Model No.	Freq. Range (GHz)	k Factor (mv/mw)	TSS (dBm)
Zero Bias			
ODZ0004A	0.1-18	1200	-51
ODZ0510A	0.5- 4	1750	-53
ODZ0518A	1.0-12	1250	-52
ODZ0527A	2.0-12	1250	-52
ODZ0328A	2.0-18	1250	-52
Tunnel Planar			
ODT0004A	0.1-18	750	-50
ODT0510A	0.5- 4	800	-50
ODT0527A	2.0-12	800	-50
ODT0328A	2.0-18	700	-50
ODT0240A	6.0-18	700	-50

COMB GENERATORS

Omniyig Model No.	Input Freq. (MHz)	Output Freq. Range (GHz)	Output Pwr. (dBm)
OHG10140	100	0.1 - 4	-10
OHG10118	100	0.1 -18	-40
OHG20218	200	0.2 -18	-34
OHG30318	250	0.25-18	-29
OHG51027	500	0.5 -18	-20
OHG61027	1000	0.1 - 18	-33
OHG72027	2000	2.0 - 18	-10
OHG61026	1000	1.0 - 26	-35
OHG71026	2000	2.0 - 26	-20

RECEIVER FRONT-END YIG FILTERS/ YIG OSCILLATORS

Omniyig Model No.	Freq. Range (GHz)	Filter IL (dB)	Tracking (MHz)
M129YTO	0.5-2	5.5	5
M120YTO	2-8	5.0	7
M121YTO	8-18	5.0	8

Oscillator RF power output +13 dBm. Integrated with Analog or 12-bit TTL drivers.

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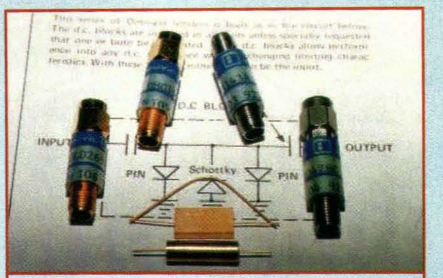

LIMITERS, COMB GENERATORS and DETECTORS

LIMITERS

Omniyig Model No.	Freq. Range (GHz)	Max. Ins. Loss (dB)	Max. Lkg. Pwr. (dBm)*
PIN Diode			
OLP2801A	0.1 - 0.5	0.5	+20
OLP2817A	1.0 - 4.0	0.5	+19
OLP2726A	2.0 - 8.0	1.2	+19
OLP2640A	6.0-18.0	2.0	+18
OLP2650A	2.0-18.0	2.5	+18
Schottky			
OLD2802A	0.1 - 1.0	0.5	+15
OLD2709A	0.5 - 2.0	0.5	+15
OLD2762A	2.0 - 8.0	1.0	+14
OLD2635A	4.0-18.0	2.5	+14
OLD2650A	2.0-18.0	2.5	+13

*Measured at 1 Watt CW Power

COMB GENERATORS with INTEGRATED INPUT RF AMPLIFIER

Omniyig Model No.	Input Freq. (MHz)	Output Freq. Range (GHz)	Output Pwr. (dBm)
CG252A	100-200	0.1 - 12	-24
CG253A	100	1.0 - 18	-38
CG256A	200	1.0 - 18	-35
CG259A	250	1.0 - 18	-30
CG265A	1000	1.0 - 18	-15
CG268A	2000	2.0 - 18	-20

COMB GENERATORS

Omniyig Model No.	Input Freq. (MHz)	Output Freq. Range (GHz)	Output Pwr. (dBm)
OHG10140	100	0.1 - 4	-10
OHG10118	100	0.1 -18	-40
OHG20218	200	0.2 -18	-34
OHG61040	1000	1.0 - 4	+2

Other designs are available with either fixed input frequencies or with variable input frequency at +28 dBm.

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NEWS

MEMS Devices Emerge At 2002 Seattle MTT-S

RF MEMS were among the technologies and products on display at this year's international microwave meeting.

JACK BROWNE
Publisher/Editor

Expectations for the 2002 Microwave Theory & Techniques Symposium (MTT-S) International Microwave Symposium and Exhibition held on June 4-6, 2002 in Seattle, WA were low, given the state of the global economy and the challenging RF/microwave business environment for more than a year. But the high-frequency industry showed its usual resolve and fortitude with a strong turnout, as more than 11,000 total attendees and exhibitors convened at the Seattle Convention Center to learn of new technologies and product developments.

One of the most visible of "emerging" technologies at the show was RF microelectromechanical systems (RF MEMS), with a half-dozen companies exhibiting either hardware or software related to the technology. Microlab, Inc. (www.microlab.net), for example, demonstrated a MEMS micromagnetic latching switch that would be suitable for wireless handsets, base stations, and multiband antennas. The switch is based on electromagnetic (EM) actuation, rather than the electrostatic technology traditionally used in RF MEMS switches.

The company's +5-VDC MagLatch RF MEMS switch features electrical contacts mounted on a nickel-iron (NiFe) pemalloy cantilever. The cantilever, which is within the field of a permanent magnet, is mounted above a planar-switching coil fabricated on a dielectric substrate. A second magnetic field is generated by passing a short current pulse through the coil. The permanent magnetic holds the cantilever in either the up (off) or down (on) position after switching without additional current.

The 50-Ω single-pole, double-throw (SPDT) switch exhibits less than 0.5-dB insertion loss from 100 MHz to 6 GHz, with insertion-loss repeatability of better than 0.05 dB. The isolation is better than 30 dB, while the maximum VSWR is less than 1.40:1 (and typically 1.20:1). The switch is rated for billions of switching cycles without significant degradation of RF performance. Although mounted in a package measuring 5 × 5 × 1.5 mm (including the magnet), the company notes that a single SPDT relay can be realized in a size of approximately 1 × 2 mm. The RF MEMS switch can be fabricated on a variety of substrates, including silicon (Si), gallium-arsenide (GaAs), glass, and ceramic types.

Coventor (www.coventor.com) displayed their SD0-35-2SPST-SOIC8 single-pole, single-throw (SPST) MEMS microrelay switch, formed of two individually controlled microrelays in an SOIC8 package. Capable of switching

1. The ASL-3000RF wireless RF-IC test system features four independent parallel measurement Rxs to make S-parameter measurements using a patented MVNA technology. (Photograph courtesy of Credence Systems Corp., Fremont, CA.)

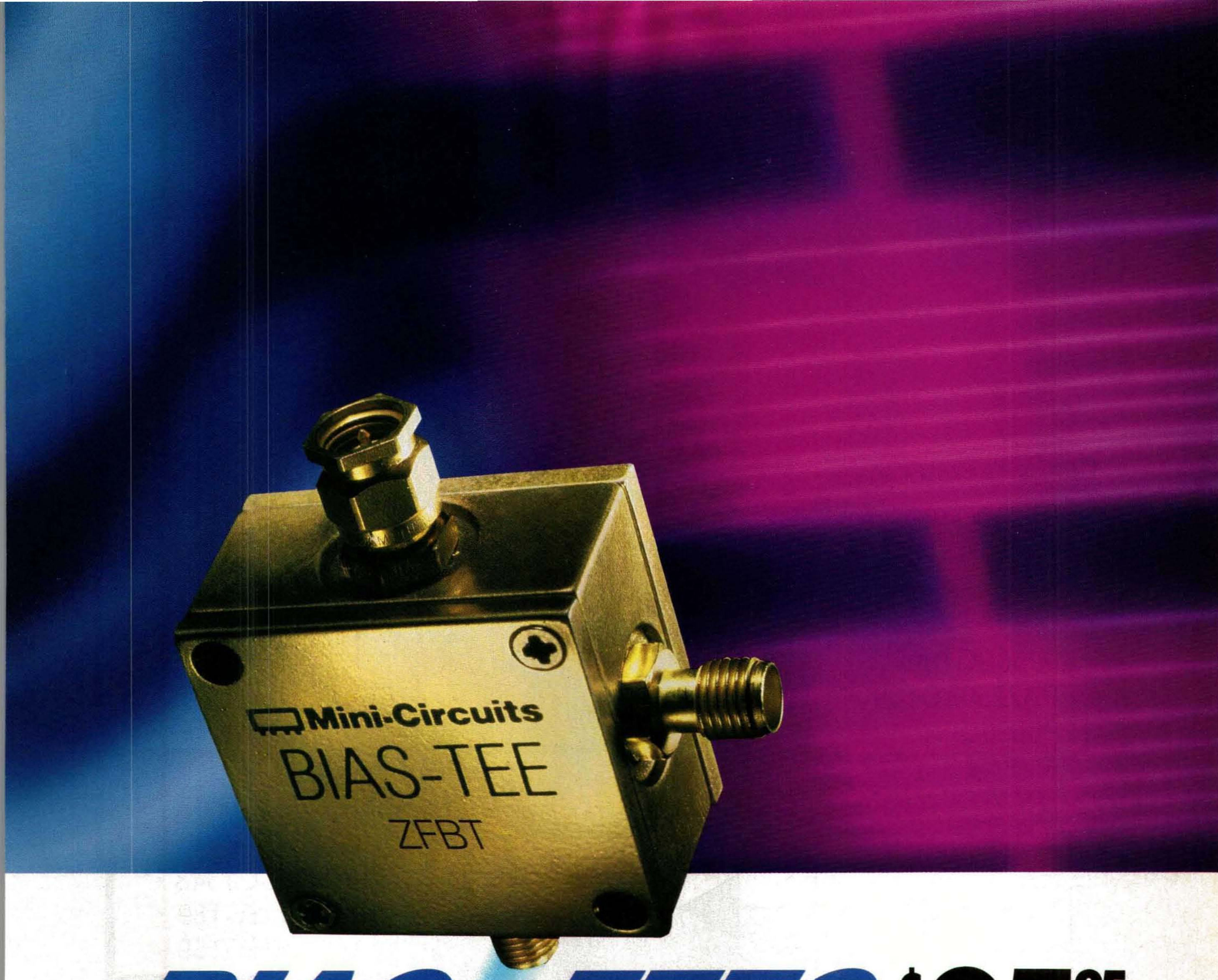
+50 VDC, the switch offers better than 50 μs switching speed with a +48-VDC control voltage. The company also offered preliminary information on its integratable SPST/SPDT RF MEMS switches for use with a variety of circuit-board and semiconductor processes and materials. The switches, which are designed for uses from DC to 40 GHz, are available as integrated post-processed devices for use with Si, Si germanium (SiGe), Si carbide (SiC), GaAs, alumina, and indium-phosphate (InP) circuits.

2. The PHASEFLEX coaxial test cable assemblies are available for frequency coverage to 65 GHz. The cables can withstand a bend radius of 1 in. (2.54-cm) without degrading performance. (Photograph courtesy of W.L. Gore & Associates, Elkton, MD.)

MEMScAP S.A. (www.memscap.com) also presented their post-processing capabilities for MEMS devices, notably high-quality-factor (high-Q) inductors. The company uses a wafer-level post-processing deposition technique to directly integrate high-Q inductors on top of a semiconductor integrated-circuit (IC) wafer. In this way, the high-performance inductors can be added to an IC to form select filters and high-performance transformers. The company has fabricated inductors with values of 1.25 and 15 at 3.0 and 1.8 GHz, respectively, with Qs of 40 and 46, respectively.

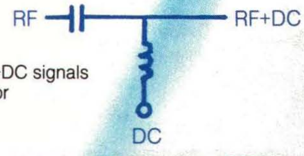
For creating MEMS designs, APLAC Solutions, Inc. (www.aplac.com) demonstrated their APLAC simulation software. The software can simulate the electrical, mechanical, and fluid behaviors of a MEMS design and analyze the behaviors in terms of DC, linear frequency, harmonic-balance, or time-domain realms. The software adds Monte Carlo yield analysis and optimization, and can be used to simulate the performance of MEMS devices in combination with conventional circuit-level components.

In the world of more "conventional" computer-aided-engineering (CAE) software, Applied Wave Research (www.mwoffice.com) announced a third-generation (3G) wideband-code-division-multiple-access (WCDMA) library for their Visual System Simulator 2002 software suite. The library supports the simulation and evaluation of wireless-communications designs for base stations and user equipment. The company also announced



BIAS TEES

From $25.95



Easily combines RF+DC signals for your modulation or test requirements.

Now up to 500mA DC current 100kHz-6GHz

With Mini-Circuits Bias-Tees, you can DC connect to the RF port of an active device without effecting its RF properties...modulate a laser, apply DC to an amplifier output, and more! Using statistical process control plus combining magnetics and microstrip, large DC currents may pass through the Bias-Tee without saturation and degradation of performance. At 1/3 to 1/4 the price of competitive units, these new Bias-Tees are available in surface mount, pin, and connectorized models. So why wait, solve your connection problems with Mini-Circuits Bias-Tees.

Mini-Circuits...we're redefining what VALUE is all about!

Model	Freq (MHz)	Insertion Loss (dB Typ.)			Isolation (dB Typ.)			VSWR (Typ.)	Price $ ea
	F_L-F_U	L	M	U	L	M	U	U	1-9 qty.
▲ZFBT-4R2G	10-4200	0.15	0.6	0.6	32	40	50	1.13:1	59.95
▲ZFBT-6G	10-6000	0.15	0.6	1.0	32	40	30	1.13:1	79.95
▲ZFBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	50	1.13:1	79.95
▲ZFBT-6GW	0.1-6000	0.15	0.6	1.0	25	40	30	1.13:1	89.95
▲ZFBT-4R2G-FT	10-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	59.95
▲ZFBT-6G-FT	10-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-4R2GW-FT	0.1-4200	0.15	0.6	0.6	N/A	N/A	N/A	1.13:1	79.95
▲ZFBT-6GW-FT	0.1-6000	0.15	0.6	1.0	N/A	N/A	N/A	1.13:1	89.95
★ZNBT-60-1W	2.5-6000	0.2	0.6	1.6	75	45	35	1.35:1	82.95
■PBTC-1G	10-1000	0.15	0.3	0.3	27	33	30	1.10:1	25.95
■PBTC-3G	10-3000	0.15	0.3	1.0	27	30	35	1.60:1	35.95
■PBTC-1GW	0.1-1000	0.15	0.3	0.3	25	33	30	1.10:1	35.95
■PBTC-3GW	0.1-3000	0.15	0.3	1.0	25	30	35	1.60:1	46.95
•JEBT-4R2G	10-4200	0.15	0.6	0.6	32	40	40	-	39.95
•JEBT-6G	10-6000	0.15	0.7	1.3	32	40	40	-	59.95
•JEBT-4R2GW	0.1-4200	0.15	0.6	0.6	25	40	40	-	59.95
•JEBT-6GW	0.1-6000	0.15	0.7	1.3	25	40	30	-	69.95

L = Low Range M = Mid Range U = Upper Range

NOTE: Isolation dB applies to DC to (RF) and DC to (RF+DC) ports.

▲SMA Models, FT Models Have Feedthrough Terminal ★Type N, BNC Female at DC

■Pin Models •Surface Mount Models

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their teamwork with TriQuint Semiconductor (www.triquint.com) for Microwave Office 2002 library support of TriQuint's TQTRx GaAs foundry process. Microwave Office 2002 is a sophisticated suite of CAE tools that includes EM and circuit simulators.

Ansoft Corp. (www.ansoft.com) showcased the Ansoft Designer suite of CAE software design and analysis tools. The suite seamlessly integrates EM-, circuit-, and system-simulation tools for analog microwave and high-speed digital design. The software allows a designer to determine the electrical behavior of a device based on its physical attributes, eliminating the need to develop electrical models based on repetitious measurements. The suite's unique "Solver On Demand" technology can automatically choose a software solver based on the nature of a design problem.

Xpedion Design Systems (www.xpedion.com) introduced Version 3.1 of their GoldenGate software, with a 10-times performance improvement over earlier versions of the RF/wireless simulation software. Version 3.1 features an innovative fast envelope transient-analysis feature for designers modeling systems with complex modulation formats, such as CDMA or quadrature-phase-shift-keying (QPSK) signals.

Several companies announced new amplifier and oscillator products. AMCOM Communications (www.amcomusa.com), for example, exhibited several low-cost power amplifiers (PAs) including the models AM053231SF-3H and AM020340SF-3H. The AM053231SF-3H operates from 0.5 to 3.2 GHz with +31-dBm output power at 1-dB compression (saturated-output capability of +32 dBm) and small-signal gain of 16 dB. It features typical gain flatness of ±2.5 dB and a built-in RF output monitoring port. The AM020340SF-3H amplifier delivers 10-W output power from 225 to 300 MHz with better than 36-dB small-signal gain across the operating band.

CAP Wireless (www.capwireless.com) displayed its various lines of low-noise amplifiers (LNAs) and PAs. LNAs included the model PS2142 GaAs field-effect-transistor (FET) cellular-band amplifier with 18-dB minimum gain from 800 to 960 MHz. With a noise figure of 1 dB and gain flatness of 1 dB, the amplifier achieves minimum output power of +16 dBm at 1-dB compression with an input IP3 of +10 dBm. The model SS032101 LNA is designed for radar and telemetry applications from 2200 to 2300 MHz. It achieves 40-dB gain with ±1-dB gain flatness and 0.6-dB maximum noise figure.

Model CS0257 is an example of the company's PAs. It is designed for microwave radio applications from 5700 to 5900 MHz, and yields 25-dB minimum gain and +26 dBm minimum output power at 1-dB compression.

Motorola's Semiconductor Products Sector (www.motorola.com/semiconductors) introduced a line of GaAs hybrid amplifiers for cable-television (CATV) applications. Operating from 40 to 870 MHz, the amplifier line includes the models MHW9186 [18.5-dB power gain at 870 MHz with –64 dB composite-triple-beat (CTB) performance at +44 dBmV/channel and 4-dB noise figure], MHW9187 (20.1-dB

power gain at 870 MHz with –71 dB CTB performance at +44 dBmV/channel and 4-dB noise figure), MHW9206 (20.3-dB power gain at 870 MHz with –64 dB CTB performance at +44 dBmV/channel and 4-dB noise figure), MHW9236 (23.9-dB power gain at 870 MHz with –64 dB CTB performance at +44 dBmV/channel and 5-dB noise figure), and MHW9247 (24.9-dB power gain at 870 MHz with –69 dB CTB performance at +44 dBmV/channel and 4-dB noise figure).

WJ Communications (www.wjcom.com) introduced the AG series of low-cost amplifier gain blocks. Based on the company's reliable InGaP heterojunction-bipolar-technology (HBT) technology, the gain blocks are designed for frequencies from DC to 3 GHz and include models with gain levels between 14.0 and 20.5 dB and output-power levels from +13 to +18.5 dBm. The output IP3 levels range from +27 to +33.5 dBm.

Ericsson Microelectronics (www.ericsson.com/rfpower) unveiled preliminary data on their PTF 102093 GOLDMOS FET, an internally matched device rated for 125-W output power from 2110 to 2170 MHz. Designed for single- or dual-carrier WCDMA operation, the +28-VDC transistor features 13.5-dB typical gain with 18.5-percent typical drain efficiency when evaluated for WCDMA use. The typical continuous-wave (CW) efficiency is 45 percent when evaluated at the 1-dB compression point.

IBM Microelectronics (www.chips.ibm.com) detailed several ICs based on their SiGe technology, including a WCDMA RF transceiver chip set. The chip set includes the IBM 5012 WCDMA transmitter (Tx), the IBM 7012 dual fractional-N synthesizer with integrated voltage-controlled oscillator (VCO), the IBM 6012 receiver (Rx), the IBM 1010 WCDMA analog baseband IC, and the IBM 2025 amplifier with on-board power control. The chip set offers a pseudo-direction-conversion transmitter operating in the IMT-2000 band from 1920 to 1980 MHz and a direct-conversion Rx for the IMT-2000 band from 2110 to 2170 MHz.

ITT Industries Microwave Systems (www.ittmicrowave.com) showed off various sources based on their direct-digital-synthesizer (DDS) technology. The STEL-2375B direct-digital chirp synthesizer, for example, can generate long-duration chirp (swept-frequency) waveforms at output frequencies from DC to 400 MHz when operating at clock rates to 1 GHz.

Raytheon RF Components (www.rrfc.raytheon.com) announced a strategic alliance with the Taiwan company WIN Semiconductor Corp. For a $5 million investment in WIN, Raytheon adds state-of-the-art manufacturing capabilities for next-generation wireless components. The alliance provides for WIN to produce 6-in. (15.24-cm) wafers using an InGaP HBT semiconductor process. Raytheon also provided information on two new additions to its PowerEdge series of PAs: models RMPA1954-106 and RMPA0954-105. The former PA module is designed for CDMA and cdma2000 personal-communications-services (PCS) applications (with +28 dBm average output power at PCS frequencies) while the latter is designed for Advanced Mobile Phone Service (AMPS) and CDMA cellular applications (with +31.5 dBm output power at cellular frequencies under analog AMPS operation).

Advanced Power Technology (www.advancedpower.com) announced the formation of Advanced Power Technology RF based on the integration of the former GHz Technology and Microsemi RF Products. The newly formed enterprise is a world leader in non-cellular/PCS high-power Si RF and microwave power transistors, serving CW and pulsed markets from very-high-frequency (VHF) and ultra-high-frequency (UHF) through L- and S-band frequencies through 3.5 GHz.

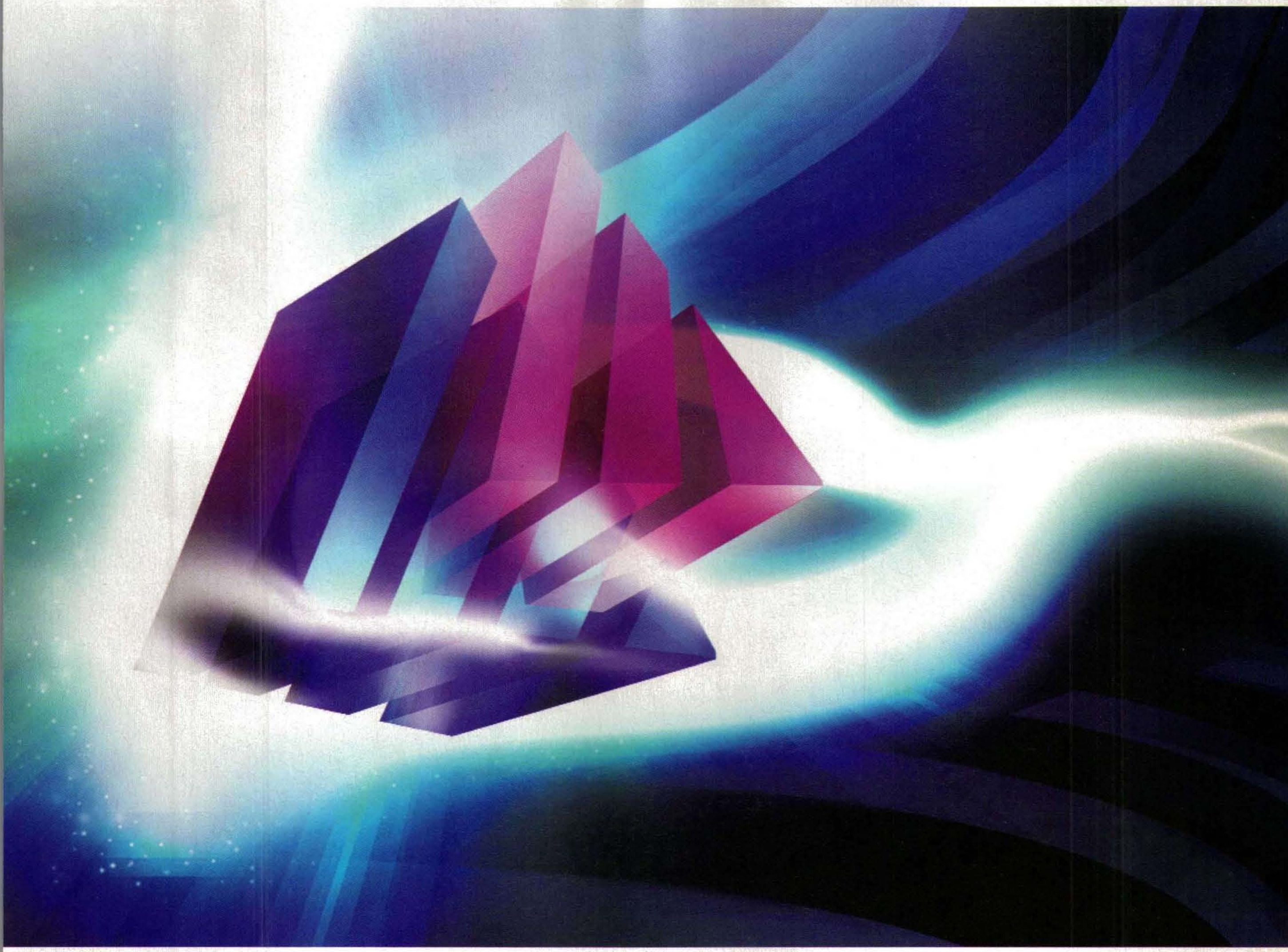
Hitachi Semiconductor (www.hitachi.com/semiconductor) displayed their GSM/General Packet Radio Service (GPRS) radio solution, which includes the HD155148F direct-conversion transceiver, the HWXQ214 integrated surface-acoustic-wave (SAW) front-end module, the HD155173ANP power-control IC, and the PF08123B PA module. The transceiver features on-chip frequency synthesizers, an offset phase-locked-loop (PLL) Tx with on-board filters, and on-chip LNAs.

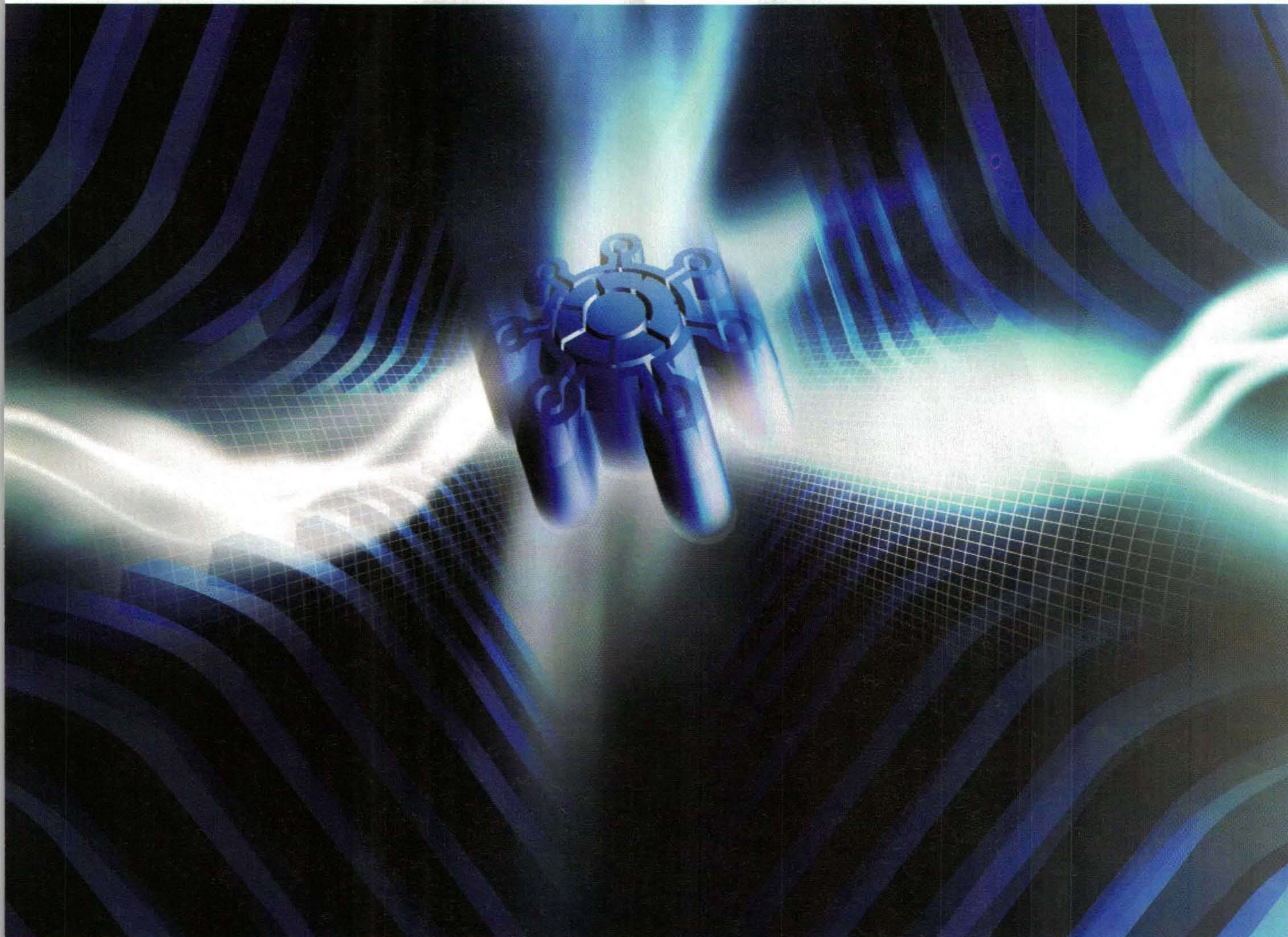
On the manufacturing side, Palomar Technologies (www.bonders.com) gave notice of the coming availability of a Flip Chip Compression Bonder for flip-chip and die attach of gold (Au)-wire ball bumps for automated assembly of RF and wireless packaged devices. The bonder is accurate and repeatable to ±5 μm. It provides a clean, lead-free process that does not require additional off-line processes to complete attachment of die to substrates. The bonder's compact 700-in.^{2} work are is well-suited for prototyping tasks, small runs, or even moderate-volume production.

In the area of test equipment, Maury Microwave (www.maurymw.com) announced that they had entered into a license agreement with Agilent Technologies that establishes Maury Microwave as the prime source for solid-state tuners based on the ATN Microwave electronic-tuner technology. The solid-state tuners, which are available for source and load-pull testing in conjunction with a vector-network analyzer (VNA), form a companion product line to Maury's existing series of mechanical source and load-pull tuners.

Celerity Digital Broadband Test (www.celeritydbt.com) demonstrated the operation of their CS2010 vector-signal generator, using a "direct-to-IF" synthesis technique to create complex waveforms. With a 14-b digital-to-analog converter (DAC) and wideband frequency upconverter (30-MHz bandwidth), the instrument can create multicarrier and complex-modulation waveforms using a variety of output filter options, including GSM (880 to 960 MHz), DCS1800 (1805 to 1910 MHz), and PCS (1920 to 1990 MHz).

Credence Systems Corp. (www.credence.com) unveiled their model ASL-3000RF wireless RF-IC test system for highly accurate scattering (S)-param-





eter measurements on wireless devices and ICs. Based on the company's patented modulated VNA (MVNA) technology, where a device under test (DUT) is evaluated with wideband, digitally modulated test signals, the test system **(Fig. 1)** features four independent parallel measurement Rxs, each with its own dedicated, high-performance digital signal processor (DSP). The parallel architecture supports extremely fast measurement speeds and allows the instrument to perform multiple measurements, such as S-parameters, ACPR, and channel power from the same set of data.

Agilent Technologies (www.agilent.com) displayed the E8361A PNA Series microwave VNA for measurements from 45 MHz to 67 GHz. The instrument achieves greater than 90 dB dynamic range through 67 GHz. It has a sweep speed of less than 26 μs/point, an integrated two-port test set, and 16 measurement channels, with capability of showing 4 traces per channel.

The company also announced the GS-9200 multicarrier PA (MCPA) test platform. The GS-9200 supports WCDMA and cdma2000 formats, but features a modular design that can be easily adapted to meet the needs of cdmaone and GSM/Enhanced Data Rates for Global Evolution (EDGE) systems. The GS-9200 features a unique display for tuning progression and interaction between tuning parameters. Multiple parameters are displayed in real time on one screen, helping customers significantly reduce MCPA tuning time.

Cascade Microtech (www.cascademicrotech.com) introduced the Wavevuew test and measurement software package. Developed by Microvue (www.microvueinc.com), the software combines all the tools needed by RF/microwave engineers to efficiently characterize high-frequency semiconductor devices. The software's capabilities include S-parameter measurements (controlling a wafer probe station and VNA), parameter transformations, generation of DC bias curves, and generation of current-voltage (I-V) curves. The company also introduced a 300-mm probe station for on-wafer characterization through 110 GHz.

Developments in passive components were also well-represented at the MTT-S. Dow-Key Microwave (www.dowkey.com), for example, introduced the model 561-5353 high-power single-pole, six-throw (SP6T) switch, capable of handling 1.5-kW CW power from DC to 1 GHz. The +28-VDC switch features maximum VSWR of 1.15:1, minimum isolation of 80 dB, and maximum insertion loss of 0.15 dB, and can be upgraded to 6.5 GHz.

Ascor, Inc. (www.ascor-inc.com) demonstrated their series 8000 General Purpose Interface Bus (GPIB) microwave switch line, with frequency coverage from DC to 18 GHz. The modular system can be configured to a customer's requirements with SPDT, single-pole, four-throw (SP4T), and SP6T switches.

StratEdge, Inc. (www.stratedge.com) announced that it had received a patent (No. NI-118360) from the Republic of China for its high-frequency passband microelectronics package. The low-cost family of DC-to-23-GHz ceramic housings provides an interconnect system with good mechanical protection and electrical performance for the GaAs monolithic-microwave-IC (MMIC) devices used in C- and Ku-band very-small-aperture-terminal (VSAT) satellite-communications (SATCOM) applications.

W.L. Gore & Associates (www.wlgore.com) announced the availability of its PHASEFLEX coaxial test-cable assemblies in frequency ranges to 65 GHz **(Fig. 2)**. The internally ruggedized microwave coaxial assemblies provide excellent phase and amplitude stability with flexure.

The company also launched the MICROLAM 600 Series Microvia Dielectric product line. The material consists of standard FR-4 epoxy resin with a continuous toughening matrix. The low-dielectric-constant (typically 2.86 for MICROLAM 610 material at 2.9 GHz) material is ideal for circuits with packaged chips, such as RF modules for Bluetooth and wireless local-area networks (WLANs). MRF

Do Not Forget the MES

JACK BROWNE
Publisher/Editor

Military business has been steady if not strong even while wireless markets have rapidly declined. In support of those engineers tasked with designing components, subsystems, software, and test solutions for military applications, the Military Electronics Show (MES) will present a wide range of technical presentations on selecting hardware, software, and test equipment in line with satisfying military customers. Scheduled for September 24-25, 2002 in the Baltimore Convention Center, the second Military Electronics Show promises two days packed with educational technical papers, workshops, and lively question-and-answer sessions. The show will also feature an exhibit area with displays from such notable manufacturers as Agilent Technologies, American Microwave, Ansoft, Avnet, M/A-COM, Noise Com, Northrop Grumman, Raytheon, and Tektronix.

Technical presentations cover a wide range of topics, with tracks focusing on antennas, analog and digital signal processing, cables/connectors, components, computer-aided engineering (CAE), computers and peripherals, electromagnetic interference (EMI)/TEMPEST, packaging and materials, power supplies and converters, receiver (Rx) and transmitter (Tx) design, simulators, and test and measurement. For a full preview of the Military Electronics Show, do not miss next month's issue of *Microwaves & RF*. And for up-to-the-minute information on the Military Electronics Show, please visit the website at www.mes2002.com.

VGA Provides 45-dB Gain-Control Range

MODEL AD8369 IS a digitally controlled variable gain amplifier (VGA) that is designed for use to 500 MHz. The unit provides a gain-control range from –5 to +40 dB that is adjustable in 3-dB increments and is controllable through a 4-b digital interface that may be configured in either serial or parallel mode. Operating temperature range is –40 to +85°C. The device has been specified for operation within receive-path automated-gain-control (AGC) loops found in cellular base-station equipment. The AD8369 is suitable for for use within third-generation (3G) equipment employing higher and wider dynamic-range intermediate-frequency (IF) sampling architectures. P&A: $4.20 (1000 qty.).

Analog Devices, 1 Technology Way, P.O. Box 9106, Norwood, MA 02062-9106; (800) 262-5643, (781) 329-4700, FAX: (781) 326-8703, Internet: www.analog.com.

● Enter No. 59 at www.mwrf.com

ANALOG DEVICES MODEL AD8369

Transistors Serve As RF Front Ends

MODELS TSDF2005W AND TSDF2020W are silicon (Si) NPN planar RF transistors are designed to serve as RF front ends for wireless communication systems up to 3 GHz. Each transistor is rated for a collector-base voltage of +10 VDC, a collector-emitter voltage of +3.5 VDC, and an emitter base voltage of +1.5 VDC. Maximum junction temperature is 150°C. The TSDF2005W features a collector current of 12 mA and total power dissipation of 40 mW at an ambient temperature of ≤132°C. The TSDF2020W features a collector current of 40 mA and maximum total power dissipation of 200 mW at an ambient temperature of ≤60°C. P&A: $12.00 per 100 pieces (100,000 qty.).

Vishay Intertechnology, Inc., 63 Lincoln Hwy., Malvern, PA 19355-2143; (610) 644-1300, FAX: (610) 296-0657, Internet: www.vishay.com.

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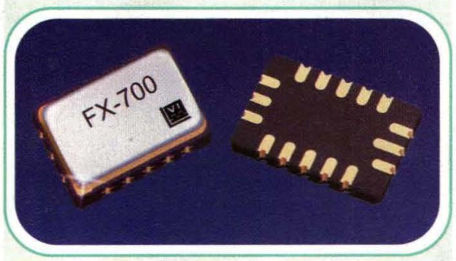
VISHAY MODELS TSDF2005W AND TSDF2020W



VECTRON MODEL FX-700

KRYTAR MODEL 6010265

Translator Offers 77.76-MHz Frequencies

MODEL FX-700 IS a crystal-based frequency translator that provides output frequency ranges from 1 kHz to 77.76 MHz with a supply voltage of either +3.3 VDC or +5.0 VDC. The device is hermetically sealed in a 16-pad ceramic surface-mount-device (SMD) package measuring 5.0 × 7.5 × 2.0 mm. The product's advanced custom application-specific-integrated-circuit (ASIC) technology results in a small, flexible option when real estate on the board is an issue. The FX-700 is suitable for Synchronous Optical Network (SONET), Synchronous Digital Hierarchy (SDH), asynchronous-transfer-mode (ATM), wave-division-multiplexer (WDM), access-node, cable-modem-head-end, and Global System for Mobile Communications (GSM) applications.

Vectron International, 166 Glover Ave., P.O. Box 5160, Norwalk, CT 06856-5160; (203) 853-4433, FAX: (203) 847-3711, e-mail: vectron@vectron.com, Internet: www.vectron.com.

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Divider Spans 1.0 To 26.5 GHz

THE MODEL 6010265 is a patented, broadband, matched-line directional divider that offers an alternative to broadband Wilkinson-designed dividers. The divider operates over the entire frequency band of 1.0 to 26.5 GHz. VSWR is 1.60:1 maximum, insertion loss is 1.6 dB maximum, and isolation is 19 dB minimum. Amplitude tracking is less than 0.3 dB and phase tracking is less than 10 deg. Specifications improve with the unit is used in the 1 to 18 GHz band. Four-way models are also offered. Applications include power and frequency monitoring, as well as summing of output power from multiple power-amplifier (PA) inputs. P&A: stock to 3 weeks.

Krytar, 1292 Anvilwood Ct., Sunnyvale, CA 94089; (408) 734-5999, FAX: (408) 734-3017, Internet: www.krytar.com.

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Northrop Grumman's Sales Up

NORTHROP GRUMMAN CORP. has reported higher sales and earnings for the second quarter that ended on June 30. Net income for the 2002 second quarter totaled $182 million, or $1.53 per share on 114.8 million average diluted shares outstanding, compared with net income of $175 million, or $2.01 per share, on 84.0 million average diluted shares in the year ago period. In the quarter, Northrop Grumman reported pension income of $23 million, a $68 million decrease compared with the same period a year earlier.

On an economic earnings basis, Northrop Grumman's second-quarter earnings increased to $188 million, or $1.59 per share, compared with $137 million, or $1.57 per share, for the comparable period in 2001.

Sales for the quarter that ended on June 30 totaled $4.4 billion, up 20 percent from the $3.7 billion reported for the 2001 second quarter. Northrop Grumman's operating margin for the quarter increased to $356 million from an adjusted $338 million reported for the same period a year ago.

"We are pleased to report another solid quarter, which included growth in all of our core defense businesses," said Kent Kresa, chairman and CEO of Northrop Grumman. "The integration of Litton and Newport News are essentially complete and our combined talents and resources are already making substantial contributions. With the continued strong operating performance and outstanding contract wins, we remain very confident in our growth and earnings prospects.

"Looking ahead, our pending acquisition of TRW will contribute meaningfully to our continued growth and add important capabilities in military space and missile defense to our already well-diversified defense portfolio," Kresa concluded.

Dr. Ronald D. Sugar, Northrop Grumman's president and COO, commented, "Our improved financial results were due in part to impressive operating-margin increases at two of our sectors. Integrated Systems sector generated a 38-percent improvement in operating margin while Electronic Systems sector reported a nine-percent increase." MRF


Military
Dow-Key Microwave
The Solutions Company
Commercial
Space
2101 SWITCH SYSTEM

CONTRACTS

TECOM Industries—Announced a contract award from Naval Air Systems Command (NAVAIR) Weapons Division in China Lake, CA. The contract, which is valued at over $1.3 million, consists of TECOM flight telemetry guidance antenna systems and command destruct antenna systems for the US Navy's AGM-88 High-Speed Anti-Radiation Missile (HARM) to be used in their missile test and evaluation program.

HARM is an air-to-surface tactical missile designed to seek out and destroy enemy radar-equipped air defense systems.

NetCom Solutions International—Has been awarded a contract to perform infrastructure and equipment installations supporting Sprint's Metropolitan Area Network (MAN) initiatives in the Phoenix, AZ and Los Angeles, CA markets. This award comes on the heels of NetCom Solutions' completion of MAN installations for Sprint in the San Francisco Bay area earlier this year.

ITS Networks, Inc.—Signed a three-year contract to provide wireless-local-area-network (WLAN) service to the Port of Benalmadena in Spain. The multiyear renewable agreement follows a trial of the wireless network operating through an antenna proprietary to the ITS network.

The 11-GB WLAN allows users to access Internet-related services within the entirety of the Port's property, as well as several miles out into the surrounding waterways. Boaters can now get traditional high-speed Internet access while away from shore, as can the shops, restaurants, and facilities in the harbor. Vacationers and travelers are able to rent wireless-enabled (WIFI) personal computers (PCs) and laptops from the Port for use while in the area.

FRESH STARTS

Ansoft Corp.—Announced the release of two software models for fuel-cell and lead-acid batteries within SIMPLORER®. The new models are intended to help engineers develop vehicle electrical systems, electric and hybrid-electric traction systems, and new +42-VDC technology for traditional internal-combustion-engine vehicles.

Aeroflex, Inc.—Announced the successful completion of a second-step merger with IFR Systems, Inc.

Computer Access Technology Corp. (CATC)—Has completed the acquisition of Verisys. The acquisition is expected to enhance CATC's position in the Storage Area Network (SAN) marketplace, complementing an existing portfolio of analyzers, which include InfiniBand and Serial ATA protocol analyzers.

PYRAmatrix Structures, Inc.—Received an SBIR Phase 1 award from the Department of Energy for the development of much-taller, lighter-weight, and lower-cost wind-turbine towers to generate electricity using PYRAmatrix T technology.

Vectron International, Inc.—Separated from its division in Neckarbischofsheim, Germany. The German location is being taken over by Manfred Klimm and will trade again under the traditional name of KVG Quarts Crystal Technology GmbH.

Geotest-Marvin Test Systems, Inc.—Announced the addition of Spectra Sales Corp. as a sales representative within the Domestic Sales Channel.

Richardson Electronics—Formed a Fiber Optic Communications business unit. Heading the group will be the business unit director, Steve Pavlik.

The newly created fiber-optic business unit will manage products globally, including passive and active components; connectors and cables; and subsystems, carrier equipment, and ancillary equipment. These products are used in the datacom, telecom, instrumentation, laboratories, and consumer industries.

Current Analysis—Launched two Professional Services modules. Delivered through CurrentCOMPUTE, the Professional Services modules analyze the activity and competitors that are driving the growth of the markets.

The E-business Solutions module covers those competitors that leverage their services capabilities to develop Internet-based solutions that create competitive advantage for businesses. Assessments focus on the respective competitors' solutions development and sales strategies, and services capabilities such as strategic consulting, application integration and development, and systems management and outsourcing.

The Telecom Solutions module examines professional services organizations that apply their engineering expertise, technical resources, and market knowledge to help service providers and large enterprises effectively leverage their telecommunication infrastructures to support their business objectives.

KDF—Has successfully completed installation of multiple in-line sputtering systems at two Taiwanese foundries. Micro Electro Magnetical Technologies Corp. (MEMT), based in Chunan, Miaoli, Taiwan, purchased a 603NT tool for critical film applications. Suntek Compound Semiconductor Co., based in Hsinchu Shien, Taiwan, ordered a 943NTX system with a planetary pallet for gallium-arsenide (GaAs) wafer production. The orders mark the first business between KDF and both companies.

EB Industries (EBI)—Appointed Robert Schaefer, Inc. (RSI) as their marketing communications counsel.

Gabriel—Has obtained a federal certificate of registration for its "Gabriel Electronics Incorporated®" trademark from the United States Trademark and Patent Office.

ITS Networks, Inc.—Relocated their headquarters and corporate offices from Marbella to Madrid, Spain. The new site will house the executive offices along with the core business activities including finance, operations, sales, marketing, technology, and customer support. MRF

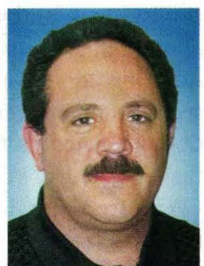
ROWE

ITT Industries, Avionics Names Rowe To VP Position

ITT Industries, Avionics Division has appointed RON ROWE as vice president and director of operations. He has been with ITT Industries for more than 25 years, spending the past two years as the Avionics Division's Value Based Six Sigma (VBSS) Champion.

Streaming21, Inc.—PATRICK DAVIS to the position of vice president of sales; formerly sales director for Asia and Europe at Symmetricon, Inc.
3DSP Corp.—DIDIER BOIVIN to president and CEO; formerly president of North American operations for DSP Group and CEO of DSP's VoicePump IC subsidiary.
Bourns, Inc.—JOHN HALENDA to president of Bourns Electronics as well as corporate vice president; formerly president of Wynn's-Precision, Inc.
KVH Industries—DR. KALYAN GANESAN to vice president of engineering; formerly employed at CoWave Networks.
Conductor Analysis Technologies, Inc. (CAT)—DAVID L. WOLF to vice president for technical marketing; formerly technology program manager for Sanmina-SCI Corp.
IPC—DOUG SOBER to chairman of the Technical Activities Executive Committee (TAEC); continues as vice president for quality assurance at GIL Technologies, Inc.
Optical Cable Corp.—NEIL WILKIN to president; remains as CFO.
EMS Technologies, Inc.—JOHN P. FRAZEE, JR. to the board of directors; formerly president and COO of Sprint Corp.
OnLine Power Supply, Inc. (OPS)—GLENN M. GRUNEWALD to CEO; formerly executive vice president and COO of Hubbell, Inc.
HUBER+SUHNER—ANDREW PAULLEY to general manager; formerly regional director of the Fiber Optic Division, EMEA with Tyco Electronics.
RF Micro Devices, Inc.—BOB BRUGGEWORTH to the position of president; formerly president of the wireless products group.
Schema Ltd.—CHAIM FORST to director of sales, EMEA; formerly CEO of the Clockwork Group.
GNP—Y.N. LEE to the position of sales manager; formerly regional strategic partner manager for the Asia Pacific for Cisco Systems.
Recognition Source—DOMINIC PIPERNO to vice president of sales; formerly vice president of sales for Indala.
ETS-Lindgren—GEORGE R. LYMAN to the position of industrial business development manager for the shielding group; formerly Pacific Northwest and Midwest regional sales manager for Schlegel Systems.
Wasabi Systems—DAVID HENKEL-WALLACE to the board of directors; continues as a partner at A.B. Scott.
Rockwell Collins—CLAYTON M. JONES to chairman of the board; remains as president and CEO. Also, DONALD R. BEALL to chairman of the executive committee; formerly chairman of the board.
Link Microtek Ltd.—MARK COZENS to technical sales engineer for the Southwest and Midlands of England; formerly GSM sales engineer with Radio Frequency Investigations.

COZENS



VALIGURSKY

Luna Technologies—EDWARD VALIGURSKY to the position of vice president of sales; previously founded Amaxim Development. MRF

▶ SHORT COURSES

Fundamentals of Radar Technology
September 24-26 (Washington, DC Area)
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September 24-27 (Madison, WI)
College Of Engineering
University of Wisconsin-Madison
Dept. of Engineering Professional Development
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Dan Danbeck (608) 262-3748
e-mail: danbeck@epd.engr.wisc.edu
Internet: http://epdweb.engr.wisc.edu/brochures/E258.html

Modern Digital Modulation Techniques
September 30-October 4 (Dallas, TX)
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Advanced Techniques for Pore Structure Characterization, Theory and Practice
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(607) 257-5544 ext. 33, FAX: (607) 257-5639
e-mail: MindyD@pmiapp.com
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Understanding 3G Wireless Technologies and Opportunities
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Marriott Marquis
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TeleStrategies
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McLean, VA 22103
(703) 734-2600, FAX: (703) 734-9371
Internet: www.telestrategies.com

GHz Interconnect Workshop
October 27-30 (Sedona, AZ)
Poco Diablo Resort
Program Chairman: David Light, VP and General Manager
Flex2Chip
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e-mail: dlight@sunright.com

▶MEETINGS

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Integrated Nanosystems 2002
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Fairfield, NJ 07007-2900
Internet: www.asme.org/nano

ION GPS 2002
September 24-27 (Portland, OR)
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Internet: www.ion.org
e-mail: meetings@ion.org

The Adhesive and Sealant Council (ASC) 2002 Fall Convention and Exposition
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Internet: www.ascouncil.org

ICALEO 2002: 21st International Congress On Applications Of Lasers And Electro-optics
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e-mail: icaleo@laserinstitute.org
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2003 International CES
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Achieve Efficient Power Control With A CMOS RF PA

WIRELESS-COMMUNICATIONS INFRASTRUCTURES use complex functionalities to optimize bandwidth use and enhance wireless personal-communications-systems (PCS) portability. Many protocols need the transmitter (Tx) power to be adjusted over a range up to 20 dB so that enough power can be received by the base station, while saving energy and reducing transmitted power and interference in other channels.

A. Shirvani, D.K. Su, and B.A. Wooley of the IEEE (New York, NY) present a complementary-metal-oxide-semiconductor (CMOS) RF power amplifier (PA) which uses parallel amplification to provide high efficiency over a wide range of output power. By dividing the power range into separate regions handled by parallel amplifiers, the authors show that the amplifier can be optimized for different sections of the power range, resulting in high efficiency over an range wider than that achieved by one PA. See "A CMOS RF Power Amplifier With Parallel Amplification for Efficient Power Control," *IEEE Journal of Solid-State Circuits,* June 2002, Vol. 37, No. 6, pp. 684-693.

Cover Multiband World Regions With A Dual-Polarized Antenna

MOBILE WIRELESS TERMINALS use separate antennas to provide multiband coverage of cellular bands. One mobile termination that can operate in multiple multifrequency world regions is the key to next-generation systems. According to B. Paul, S. Mridula, C.K. Aanandan, and P. Mohanan of the Center for Research in Electro-Magnetics and Antennas (Kerala, India), these needs mandated the creation of a low-cost, compact, highly reliable integrated antenna without moving parts that can navigate various world frequencies.

A dual-polarized antenna meeting these requirements features a cross polarization of better than –25 dB, ensuring suppression of crosstalk in polarization-diversity systems. See "A New Microstrip Patch Antenna For Mobile Communications and Bluetooth Applications," *Microwave and Optical Technology Letters,* May 20, 2002, Vol. 33, No. 4, pp. 285-286.

Investigate Noise Performance Of MM DHBTs On GaAs Substrates

INDIUM-PHOSPHATE/INDIUM-GALLIUM-ARSENIDE (InP)/(InGaAs) heterojunction bipolar transistors (HBTs) lattice-matched (LM) to InP have shown better performance than GaAs HBTs due to InP/InGaAs material's superior transport properties and surface recombination velocity. Yong Zhong Xiong, Geok-Ing Ng, Hong Wang, and Jeffrey S. Fu of Nanyang Technological University (Republic of Singapore) examine the microwave noise performances of metamorphic (MM) InP/InGaAs/InP double HBTs (DHBTs) on GaAs substrates.

The noise figures and associated gains of the device with an emitter size of $5 \times 5\ \mu m^2$ are investigated in the 2-to-10-GHz frequency range and variations of minimum noise figure at different collector currents are listed. At 2 GHz, the best minimum noise figure of 2.1 dB with an associated gain of 12.7 dB were achieved by V_{CE} = +1.5 VDC and I_C = 0.3 mA. For comparable size and current density, the authors' results prove noise performance that can be compared to that of reported LM InP HBTs at approximately 2 GHz. See "Microwave Noise Performance Of Metamorphic $InP/In_{0.53}Ga_{0.47}As/InP$ DHBT on GaAs Substrates," *Microwave and Optical Technology Letters,* May 20, 2002, Vol. 33, No. 4, pp. 306-308.

Examine New Optical SATCOM System Developments

SATELLITE COMMUNICATION (SATCOM), particularly personal communications services (PCS) using the geostationary-earth-orbit (GEO), low-earth-orbit (LEO), medium-earth-orbit (MEO), and intermediate-circuit-orbit (ICO) satellite systems, is gaining momentum with optical SATCOM techniques showing promising developments. Shyh-Lin Tsao, Hao-Chih Yu, and Yi-Chih Lin of the Yuan Ze University Chung-Li (Taiwan, P.R.C.) explore the developments of a new optical SATCOM system with a local oscillator (LO) in the transmitter (Tx) and one in the receiver (Rx) station.

The authors propose a new microwave-photonic Rx for accepting the stabilized microwave reference note. The optical SATCOM system transmits a 2.5-Gb/s frequency-shift-keying (FSK) signal. Satellite vibration, beam divergence, atmosphere absorption, and scattering are examined. See "Analysis Of An Optical Satellite Communication System With Stabilized Microwave Reference Note Transmission," *Microwave and Optical Technology Letters,* May 5, 2002, Vol. 33, No. 3, pp. 149-151.

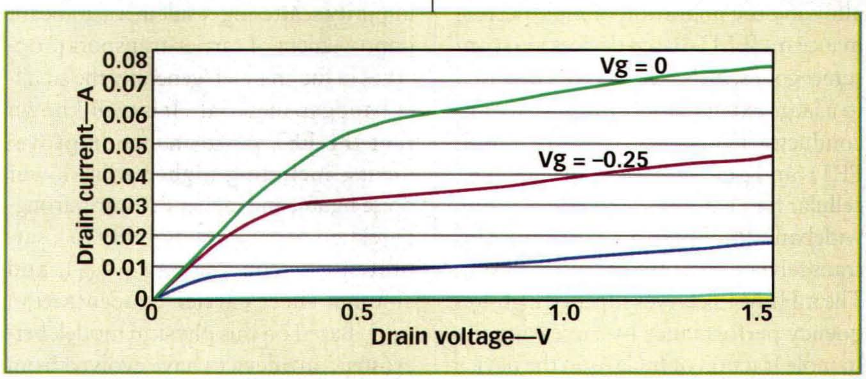
Novel mHEMTs Signal Transistor Evolution

The mHEMT offers considerable advantages over traditional pHEMT devices, especially for applications requiring moderate power.

T. HWANG
Staff Scientist
Filtronic Solid State Semiconductor, 3251 Olcott St., Santa Clara, CA 95054.

Gallium-arsenide (GaAs) pseudomorphic High Electron Mobility Transistors (pHEMTs) are well-known for their high current gain at high cutoff frequencies (typically 50 to 60 GHz at 25 percent I_{DSS} for a quarter-micron-gate-length device). And indium-phosphate (InP)-based HEMT devices have traditionally been used for millimeter-wave applications. But with the expanding use of 38 GHz and higher (66 and 77 GHz for automotive collision-avoidance and communications applications and 40-Gb/s for OC-768 optical-communications systems), the use of GaAs-based metamorphic-HEMT (mHEMT) technology looks promising for millimeter-wave applications and low-noise applications at lower frequencies, such as 12-to-23-GHz direct-broadcast-satellite (DBS) systems requiring high gain.

The demand for more bandwidth, coupled with the crowding of the lower-frequency bands, continues to force improvement in fundamental device performance. To meet emerging requirements, there has been a considerable amount of work on InP-based HEMTs over the last decade.[1-5] The InP-based indium-aluminum-arsenide (InAlAs)/InGaAs material structure with an InGaAs channel of 53-percent In has advantages of higher bandgap discontinuity and higher saturation velocity, thereby leading to better performance at higher frequencies compared to GaAs-based pHEMTs. Performance improvements included higher gain, better power density, and higher power-added efficiency (PAE). However, manufacturing these devices in high pro-



These plots show the current-voltage (I-V) characteristics for a 0.15 × 200 μm mHEMT device with 53-percent In channel.

Table 1: Band diagram characteristics

Heterojunction	AlGaAs(Al:20%)/GaAs	AlGaAs(Al:20%)/InGaAs(In:20%)	InAlAs(In:40%)/InGaAs(In:40%)	InAlAs(In:52%)/InGaAs(In:53%)
Δ Ec (eV)	0.22	0.30	0.70	0.48
Δ Ec (eV)	0.15	0.25	0.30	0.24
ΔΓ – L (eV)	0.31	0.40	~0.58	0.58

duction volume is difficult due to the brittle nature of InP substrates, higher cost (than GaAs), and small available wafer size. For instance, GaAs is already available in 6-in. (15.24-cm)-diameter wafers versus the 4-in.(10.16-cm)-diameter wafers commonly available for InP.

In addition, the penalty of increasing In composition in the device channel is generally a decrease in breakdown voltage due to enhanced impact ionization in the smaller bandgap material. InP-based HEMTs traditionally have lower breakdown voltages than GaAs-based pHEMTs, severely limiting achievable power density.[6,7] Recently, GaAs-based mHEMT technology has emerged as an attractive, low-cost alternative to InP HEMTs.[8-10] In this new approach, metamorphic buffers are used to accommodate the lattice mismatch between the GaAs substrate and the active layers.[11-12] Using the metamorphic buffer concept, unstrained InAlAs/InGaAs heterostructures can be grown with approximately any InAs mole fraction, and consequently the In content can be considered as a new structure parameter. With the previous limitation overcome, it is now possible to achieve the superior frequency performance of InP-based HEMT devices, whilst remaining on GaAs substrates. This significant cost savings has the potential of allowing the migration of high-performance mHEMT-based devices into consumer goods, such as has already occurred to a large extent with GaAs metal-semiconductor-field-effect-transistor (MESFET)- and pHEMT-based devices [i.e., cellular handset power amplifiers (PAs), wideband-local-area-network (WLAN) transceivers, and DBS receivers (Rxs)]. The mHEMT achieves superior high-frequency performance by increasing the In mole fraction of InGaAs in the device channel. Metamorphic HEMT technology has the potential to eventually displace InP HEMT technology in millimeter-wave applications.

Filtronic Solid State (FSS; Santa Clara, CA) has developed an ultrafast InAlAs/InGaAs/GaAs mHEMT technology for low-noise and medium-power applications. High-power applications, especially beyond a drain-source voltage (V_{DS}) of +8 VDC, will be evaluated and developed in the near future. These mHEMTs have demonstrated improved noise figures and power performance compared to the company's existing standard pHEMT devices. Performance improvements include higher gain, lower noise figure, and higher PAE.

Discovery of the two-dimensional electron gas (2 DEG) at the AlGaAs/GaAs hetero-interface was a major breakthrough in the evolution of the FET device family.[13] Advances in materials-growth technology, such as molecular-beam-epitaxy (MBE) systems, led to the fabrication of devices composed of heterojunctions (junctions between dissimilar semiconductors). Heterojunctions have the unique property of providing conduction- and valence-band discontinuities (gaps in the allowed energy levels). The resulting quantum confinement of the carriers (electrons for a unipolar FET) created by the heterostructure, and the associated modulation doping, which reduces ionized impurity scattering result in a significant improvement of carrier-transport properties in the channel (generally the smaller bandgap material). It is well-known that the FET-performance improvements, including higher gain, lower noise figure, and higher PAE, are strongly related to electron mobility (μ), saturated electron velocity (v_{SAT}), and channel sheet carrier concentration (n_{so}). Based on this physical model, heterostructure devices have evolved from the AlGaAs/GaAs HEMT to the AlGaAs/InGaAs (with 15-to-25-percent In content) pHEMT, then from the InAlAs/InGaAs (with 53-percent In content) InP HEMT to the InAlAs/InGaAs (with more than 53-percent In content) InP pHEMT and, finally, the InAlAs/InGaAs/GaAs mHEMT. Indeed, mHEMTs and InP HEMTs with identical active-layer design exhibit approximately identical DC and RF characteristics. However, mHEMTs avoid many of the disadvantages of the InP HEMTs.

Introduction of In to the channel reduces the bandgap (i.e., increases the discontinuity at the heterojunction) and improves n_{so} significantly. **Table 1** summarizes the conduction-band discontinuity (ΔE_C), the valence-band discontinuity (ΔE_V), and the energy separation between the Γ and L valleys (ΔΓ-L) of AlGaAs/GaAs,14 AlGaAs/InGaAs, InAlAs(40-percent In)/InGaAs(40-percent In),[15] and InAlAs(52-percent In)/InGaAs(53-percent In).[14] InAlAs/-InGaAs heterojunctions not only have higher ΔE_C but also larger ΔΓ-L separation. The devices with larger ΔΓ-L provide higher speed at high electric fields because more electrons with smaller m_{eff} stayed at the Γ valley. In Table 1, the high ΔE_C of 0.48 eV for the InAlAs(52-percent In)/InGaAs(53-percent In) heterojunction leads to high sheet-carrier density n_{so} and good carrier confinement (carrier confinement relates to maintaining high device transconductance under conditions of higher DC bias). Obviously, InAlAs(40-percent In)/-InGaAs(40-percent In) has the higher ΔE_C and better Schottky characteristics than InAlAs(52-percent In)/InGaAs(53-percent In) does.[16] In addition to these, InGaAs(40-percent In) has a wider bandgap than InGaAs(53-percent In), which offers a higher on-state breakdown voltage. However, InAlAs(52-percent In)/-InGaAs(53-percent In) has a smaller effective mass, m_{eff}, which strongly affects the DC and RF device characteristics. In the equation, the smaller m_{eff} induces higher mobility (μ) and velocity (v_{SAT}). The higher In mole fraction of InGaAs in the channel reduces m_{eff} even further:

$$\mu = e\tau / m_{eff},\ \tau = Lg / v_{SAT}$$

Table 2: Layout, DC characteristics, and breakdown voltage

Device	D-G spacing (μm)	S-G spacing (μm)	Idss (mA/mm)	gm (mS/mm)	BVg-d (V)	BVon-state (V)
0.15 μm FSS standard pHEMT	1.62	1.13	260	420 ~ 450	8 ~ 9	8 ~ 9
0.15 μm & 53% In mHEMT	1.62	1.13	350	600 ~ 635	6 ~ 7	4
0.15 μm & 53% In mHEMT	2.40	1.45	340	500 ~ 520	7 ~ 8	5
0.15 μm & 40% In mHEMT	1.62	1.13	320	550 ~ 580	8 ~ 9	6.5
0.15 μm & 46% & 53% In composite channel mHEMT	2.40	1.45	370	780 ~ 820	4	4 ~ 4.5

where:

τ = the average time between the electron being scattered (by impurities or by the lattice), and L_g = the gate length of the device.

Many researchers have believed that the enhanced impact-ionization effect, which occurs in a narrow-bandgap InGaAs channel, has a number of negative consequences, especially reduced off-state and on-state breakdown voltages. Insufficient breakdown voltage will limit the use of a device for large-signal, high-power applications, even for low-noise devices. Several approaches to enhance the breakdown voltage of mHEMTs have been introduced.[8,17,18] At FSS, three approaches were evaluated to enhance gate-to-drain breakdown (BV_{gd}) and on-state avalanche breakdown ($BV_{on\text{-}state}$) voltages: 1) using a lower in-channel In mole fraction; 2) using wider drain-source spacing; and 3) using a composite channel (combining different In mole fractions in the device channel). In addition to these approaches, platinum/titanium/platinum/gold (Pt/Ti/Pt/Au) gate metal with optimum annealing was used to enhance $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$. Pt-based gate metal improves the Schottky barrier height, enhances the gate-to-drain breakdown voltage, and reduces the gate-leakage current.[19] An increase of on-state breakdown voltage might be attributed to the slight improvement of kink, but it could also be due to annealing of any damages or dangling bonds created during gate-recess near the gate periphery.[19]

Table 2 summarizes the $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$ voltages resulting from varying parameters, D-G spacing, In mole fraction, and composite channel for the three approaches. Pt/Ti/Pt/Au gate metal was used for all devices (listed in Table 2). Ti/Pt/Au gate metal was also evaluated on an mHEMT device with 53-percent In. The $BV_{on\text{-}state}$ of devices with Pt/Ti/Pt/Au yielded a drain-source voltage of +4 VDC rather than +3 VDC with the Ti/Pt/Au metal. From Table 2, the mHEMT devices with 40-percent In for the channel and Schottky layer improved $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$ voltages. However, it suffered a decrease of transconductance (g_m), which strongly affects RF performance. The design of a device epistructure is greatly dependent upon the application of that particular device. Wider drain-gate spacing improves not only $BV_{g\text{-}d}$ but also $BV_{on\text{-}state}$ performance. In Table 2, $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$ of the mHEMT with 53-percent In content increased approximately +1 VDC when the drain-gate spacing was changed from 1.62 to 2.4 μm. The longer path between the gate edge to the N^+ drain edge reduces the strength of the electric field. The weaker electric field along the path then enhances $BV_{g\text{-}d}$ and reduces the impact-ionization effect.

Device Fabrication

Metamorphic HEMTs with 0.15-μm gate length were fabricated on epitaxial wafers using a recessed-gate FET process. Device isolation was achieved by mesa etching. Source and drain regions were optically defined, followed by gold/germanium/nickel/gold (Au/Ge/Ni/Au) ohmic metal evaporation. Optimum alloy conditions (temperature and time) were based on the In mole fraction and doping concentration of capped epitaxy wafers. These conditions yielded typical contact-resistance numbers in the range of 0.04 to 0.06 Ω-mm for low-noise FETs and 0.15 to 0.2 Ω-mm for power FETs with double doping layers. The contact resistance was measured through the Transmission Line Model (TLM) technique. Following ohmic formation, gate etching was performed by selectively removing the InGaAs cap layer and stopping on the InAlAs barrier layer. The gate process was completed with Pt/Ti/Pt/Au metal evaporation and lift-off. Devices were immediately nitride passivated to stop oxidation of the recessed area and mechanically stabilize the gate. Airbridge metal was employed for source pad connections. Finally, the wafer was thinned to lower the source inductance and to provide good thermal dissipation.

Typical DC current-voltage characteristics for 0.15 × 200 μm (53-percent In) mHEMTS fabricated at FSS are shown in the figure. The kink normally occurred for V_{DS} between +0.5 and +1 VDC. This kink is associated with reduced gain and excess noise at high frequencies with high V_{DS} operation and also related to on-state breakdown and premature burnout.[17] From the corresponding plot of extrinsic transconductance (g_m) and drain current versus gate voltage at a drain-bias voltage of +1.5 VDC, an maximum extrinsic transconductance (g_{max}) of 635 mS/mm was obtained at a drain current of 240 mA/mm. Good pinchoff characteristics were observed with a pinchoff voltage of typically –0.75 VDC. The gate-to-drain breakdown voltage was measured as +6 to +7 VDC, defined as 1 mA/mm; the on-state avalanche breakdown voltage occurred at V_{DS} = +4 VDC, which biased at I_{DS} = 180 mA/mm. Devices with InGaAs (40 percent In) were also evaluated. These devices showed lower g_{max}, typically in the range of 550 to 580 mS/mm. However, $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$ increased to +8 to +9 VDC and +6.0 to +6.5 VDC, respectively. Sufficient $BV_{g\text{-}d}$ and $BV_{on\text{-}state}$ are required for low-noise and medium-power applications.

The mHEMT scattering (S)-parameters were measured over the 0.5 to 18.0 GHz frequency range, at bias conditions of V_{DS} = +1 VDC with 50-percent I_{DSS} and 25-percent I_{DSS}. Current gains as a function of frequency were calculated from the S-parameters. Extrapolation of the current gain to unity for devices with 53-percent In channel content using a suitable 6-dB/octave slope yields f^T = 125 GHz

Table 3: RF performance of mHEMTs

Device \ RF performance	fT (25% I_{DSS})	fT (50% I_{DSS})	NF	Ga	NF (pkg)	Ga (pkg)	P-1 dB	G-1 dB	PAE
FSS pHEMT	75 GHz	82 GHz	0.60 dB	14.2 dB	0.72 dB	13.1 dB	11.03 dBm	16.58 dB	24.40%
mHEMT (53% In)	110 GHz	125 GHz	0.50 dB	15.9 dB	0.60 dB	15.0 dB	13.34 dBm	18.51 dB	33.50%
mHEMT (40% In)	95 GHz	115 GHz	0.55 dB	14.5 dB	0.65 dB	13.5 dB	14.58 dBm	17.62 dB	34.86%

(Table 3). FSS's standard low-noise pHEMT, tested at V_{DS} = +2 VDC, is included Table 3 as a reference.

Noise measurements were performed from 4 to 16 GHz using a wafer probe station from Cascade Microtech (Hillsboro, OR) and a NPT 18 noise parameter test set from ATN Microwave/Agilent Technologies (Santa Rosa, CA). Biasing conditions were V_{DS} = +2 VDC, I_{DS} = 10 mA and V_{DS} = +1 VDC, I_{DS} = 15 mA for the pHEMT and mHEMT devices, respectively. The minimum noise figures and associated gains at 12 GHz are summarized in Table 3. Further optimization of the device layout can reduce gate resistance (R_g), which will improve noise figure and associated gain. The noise figure and associated gain of devices in ceramic packages were also measured, using the same biasing conditions as for the on-wafer measurements (see Table 3). Metamorphic HEMTs were also evaluated for bias of V_{DS} = +1.5 VDC and I_{DS} = 15 mA. Compared to bias at +1 VDC, the noise figures typically increased by approximately 1 dB, possibly attributable to the influence of the kink effect.

The mHEMT devices with 53-percent In have the lowest noise figure, the highest gain, and are good candidates for low-noise applications. Such devices are limited for higher-voltage operation due to their low breakdown voltage, especially on-state breakdown. Metamorphic HEMTs with 40-percent In offer very similar performance to pHEMTs for low-noise applications, albeit with better power performance than pHEMTs.

Drain bias limits of +3 VDC have hampered the output power of mHEMT and InP HEMT devices with high-In-content channels, especially 53-percent In. Low on-state breakdown voltage predominately limits the use of these devices in high-power applications. Preliminary power performance was measured at 6 GHz on FSS's 0.15 × 200 μm single recess pHEMT and mHEMT devices **(see figure)** [see Table 3].

The 0.15 × 200 μm devices were also evaluated in P70 plastic packages. Power measurements were performed on the packaged devices using a Microwave EM

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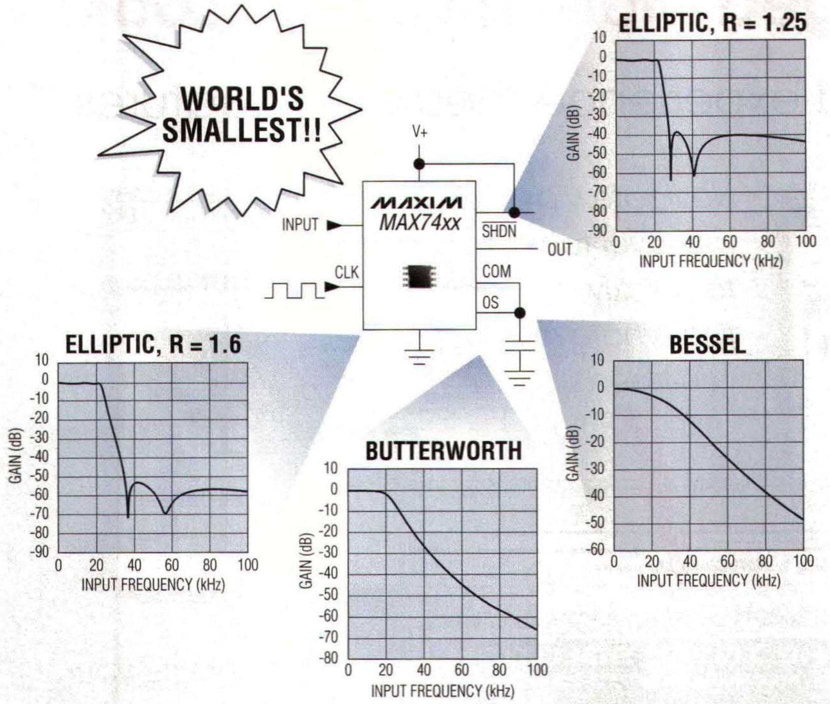

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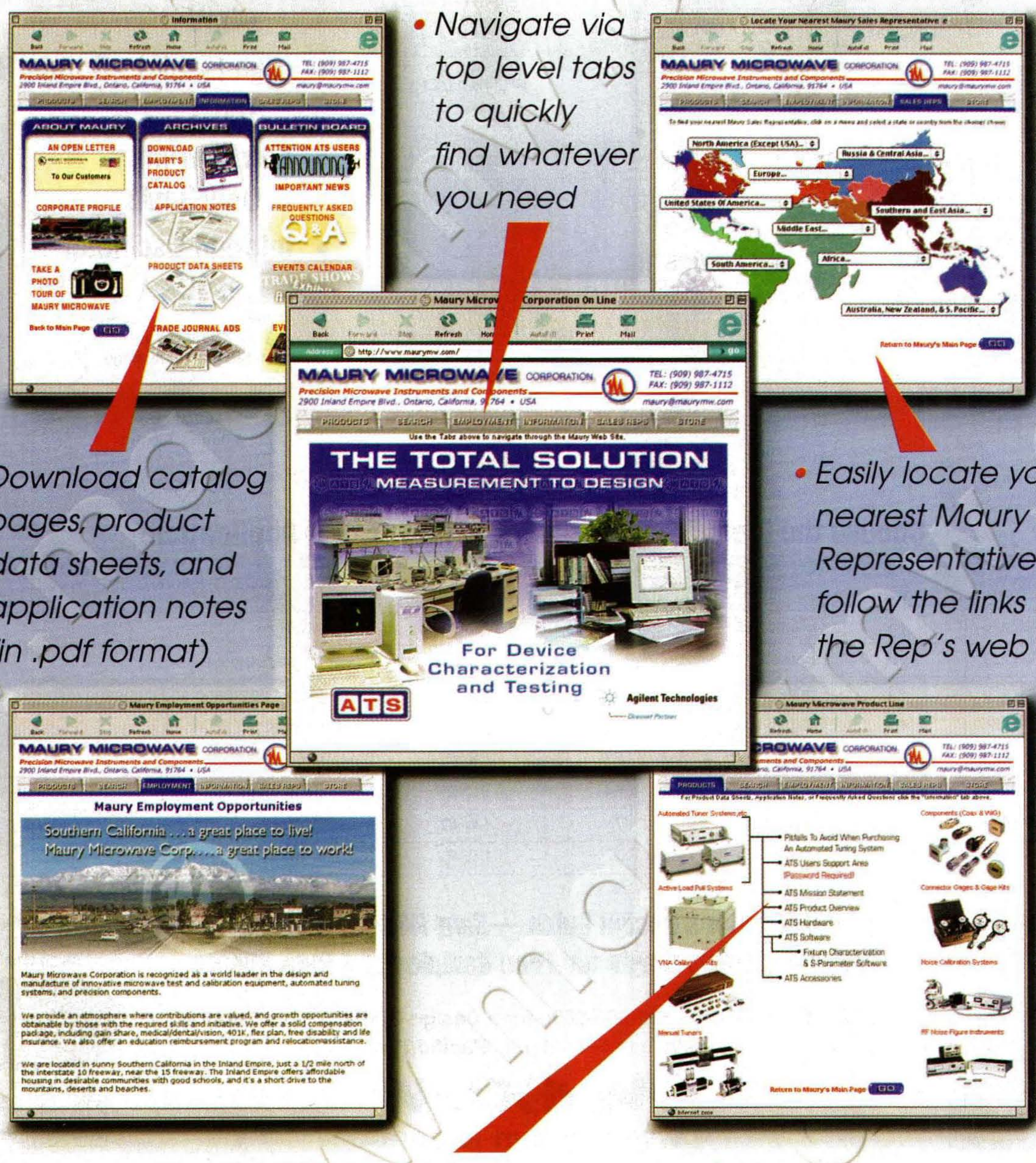

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Load Pull System from ATN Microwave/Agilent and a model 8510B vector-network analyzer (VNA) from Agilent. The gain and output power at 1-dB compression, PAE under Class A bias conditions, and +2-VDC drain-to-source voltage are shown in Table 3. The mHEMT with 53-percent In content has the highest gain (due to the highest In content in the channel). However, the 53-percent In devices also easily burn out at +3 VDC V_{DS} under Class A operation. The other devices, the pHEMTs and mHEMTs with 40-percent In channels, operated well at +3 VDC V_{DS}. The mHEMT with 40-percent In channel can operate at V_{DS} = +3 VDC with higher gain and PAE than a pHEMT.

An mHEMT with a 40-percent In channel can operate at V_{DS} = +3 VDC with higher gain and PAE than a pHEMT. It is believed that an mHEMT with an optimized process and epistructure can replace pHEMTs for low-noise and medium-power applications. Meanwhile, the epistructures and processes for double-recess devices are being developed at FSS for high-power applications, especially at +8 VDC.

Metamorphic HEMTs offer distinct advantages over GaAs and InP HEMT technologies. Metamorphic technology is competitive with InP for cost-driven mass-market applications, especially given the need for high volumes and large wafer sizes. Metamorphic HEMTs feature the freedom to choose the optimum In content for the InGaAs channel to accommodate a wide range of applications, including low-noise and power FETs and monolithic-microwave integrated circuits (MMICs). In effect, a device designer can optimize the In mole fraction for a particular application. For example, low-noise amplifiers (LNAs) might require reverse breakdown voltage ratings of +6 to +8 VDC and on-state breakdown voltages of at least +5 VDC for operation at a drain-source bias of +2 to +3 VDC. For this case, the In content could be increased for higher transconductance and wider frequency response. For medium-power applications (to 0.5-W output power), the device might require a bias of +5 VDC, with reverse breakdown voltage and on-state breakdown voltages of at least +10 to +12 VDC. The In content could then be lowered to ensure adequate breakdown performance, at the expense of somewhat less maximum transconductance.

Optoelectronic IC (OEIC) fabrication using metamorphic technology is also of considerable interest to enhance the cost-effectiveness of photoreceivers. For example, InGaAs MSM photodiodes have been combined monolithically with a

AlGaAs/GaAs HEMT device; here the AlGaInAs graded buffer at the base of the diode structure transitions from the InGaAs absorption layer to the AlGaAs HEMT Schottky layer.[20,21] Alternatively, the InGaAs PIN structure can be combined with an mHEMT device, with the AlGaInAs graded buffer layer below the transistor structure. These compound structures are fabricated on semi-insulating GaAs substrates. These monolithic photoreceivers have demonstrated adequate responsivity and bandwidth for long-wavelength operation (1330 and 1550 nm) at OC-192 speeds (10 Gb/s). There is also the attractive possibility of combining laser structures with electroabsorptive or light-guiding structures, thereby allowing multiple functions to reside on the same monolithic chip. The metamorphic techniques illustrated at this present work have the potential to entirely eliminate the need to fabricate devices on InP substrates. MRF

ACKNOWLEDGMENTS

The author would like to acknowledge the support of Deon Glajchen who is critical to the success of FSS's mHEMT project. The author would also like to thank to D. Lagman for technical support, M. Bailey for invaluable discussion and comments, and Dr. J. Leanes and S. Xie for RF testing support.

REFERENCES

1. L.D. Nguyen *et al.*, *IEEE Transactions on Electron Devices*, p. 2007, September 1992.

2. T. Enoki *et al.*, *Jpn. Journal Appl. Phys.*, Part 1, p. 789, January 1994.

3. T. Suemitsu *et al.*, *IEDM Technical Digest*, p. 223, 1998.

4. P.M. Smith *et al.*, *IEEE Microwave and Guided Wave Letters*, p. 230, July 1995.

5. P.M. Smith, *IEEE Transactions of the MTT*, p. 2328, December 1996.

6. Y.C. Pao *et al.*, *Third International Conference on InP and Related Compounds*, p. 344, 1991.

7. M. Chertouk *et al.*, *Seventh International Conference on InP and Related Compounds*, p. 737, 1995.

8. M. Chertouk *et al.*, *IEEE Electron Device Letters*, Vol. 17, p. 273, 1996.

9. P. Win *et al.*, *Electron Letters*, Vol. 29, p. 169, 1993.

10. M. Kawano *et al.*, *IEEE Microwave and Guided Wave Letters*, Vol. 7, p. 6, 1997.

11. M. Haupt *et al.*, *Appl. Phys. Lett.*, Vol. 69, No. 3, pp. 4-12, July 15, 1996.

12. J. Shieh *et al.*, *J. Appl. Phys.*, Vol. 82, No. 1, p. 210, July 1, 1997.

13. H.L. Stormer *et al.*, *Solid-State Communications*, Vol. 29, p.705, 1979.

14. R. Driad, *National Research Council Report.*

15. M. Zaknoune *et al.*, *IEEE Electron Device Letters*, Vol. 19, p. 345, September 1998.

16. S. Bollaert *et al.*, *IEEE Electron Device Letters*, Vol. 20, p. 123, 1999.

17. G. Meneghesso *et al.*, *IEEE Electron Devices*, Vol. 46, p. 2, 1999.

18. C.S. Whelan *et al.*, *GaAs ManTech*, p. 237, 2000.

19. D.C. Dumka *et al.*, *IEEE Electron Device Letters*, Vol. 22, No. 8, p. 364, 2001.

20. G. Rondeau *et al.*, *Compound Semiconductor*, Vol. 6 No. 7, p. 83, September/October 2000.

21. V. Hurm *et al.*, *IPRM'97 Conference Proceedings*, p. 197, 1997.

Engineering Applications of the Modulated Scatterer Technique

JEAN-CHARLES BOLOMEY AND FRED E. GARDIOL

Engineering Applications of the Modulated Scatterer Technique introduces the field of modulated scattering and general overview beginning with basic concepts and ending with recent developments. The book is presented in an easy-to-understand forum that includes basic theory, principles of design, and implementations. The text presents MST measurement setups for analyzing EM field distributions in a wide variety of applications.

Chapter 1 presents the general context of MST development and describes the main reasons for development. The text includes significant features of techniques that enable EM field probing and the collection of detailed maps even in the close vicinity of antennas and devices. Topics include near-to-far field transformations, near and far field basics, comparison of direct and indirect measurements, large antenna measurements, and computer simulations.

Chapters 2 and 3 provide fundamental notations of EM theory needed to understand MST setup operation and acquisition principals for their design. The effects produced by an EM field on a probe are discussed as they apply to direct and indirect measurements, modes of operation, and the nominal environment showing MST's similarity to monostatic and bistatic radars.

Chapter 4 and 5 are devoted to implementation of mobile probe systems and present the theoretical background and a selection of practical realizations. Mobile probe configurations are characterized by a low invasiveness, and are therefore the preferred choice for measurements in the very near field of devices and antennas. Chapter 4 introduces a standard measurement layout and describes the operation of its components. Some typical probes are shown, and fundamental Rx requirements are outlined.

Chapter 5 then shows how mobile probe test setups were implemented and the main institutions that make use of them. The practical interest of the technique is then illustrated by a selection of field plots and distributions derived from MST measurements for antennas, transmission lines, circuits, amplifiers, guiding structures, industrial applicators, and portable phones.

In a similar manner, Chapters 6 and 7 consider the applications of probe arrays for rapid measurement. Both chapters are respectively devoted to the presentation of the theoretical background and then to the description of practical implementations. Chapter 6 shows how the use of modulated probe arrays can drastically reduce the time needed to measure large field plots, while also reducing the amount of measured data. It shows how arrays of various architectures and technologies can be adjusted to optimize the measurement characteristics. The sensitivity and uniformity aspects are considered in some detail, and calibration techniques are briefly described. It is shown how, by carefully adjusting the amplitude and phase of the modulating signals fed to the different elements of the array, one can directly obtain the far-field antenna pattern (at infinity), and the antenna pattern at a finite distance.

Chapter 7 shows how modulated array setups are implemented, to characterize large communication and radar antennas when little space is available to make the measurement. Several configurations for the measurement of the radar cross section are presented, showing how the measurement time can be reduced by several orders of magnitude.

Finally, the MST approach provides interesting possibilities in ISM applications with microwave tomographic imagery. The practical interest of modulated arrays in all these areas is illustrated by a selection of field plots and distributions, derived from actual MST measurements. Chapter 8 sums up the main features of the technique and outlines potential future developments. (2001, 255pp., hardcover, ISBN: 1-58503-147-4, $83.00.) **Artech House, Inc., 685 Canton St., Norwood MA 02062; (781) 769-9750, FAX: (781) 769-6334, Internet: www.artech-house.com.**

Printed Dipole Antenna Has Integrated Balun For 5-GHz WLANs

This simple printed dipole antenna design provides adequate gain and a low-cost solution for high-data-rate 5-GHz WLANs.

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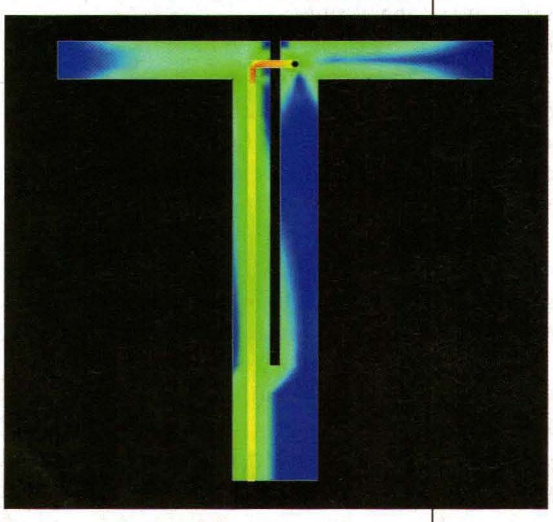
Wireless local-area networks (WLANs) have gained popularity with the growth of mobile Internet services. WLAN development in the 5-GHz band (the IEEE 802.11a and g standards) is especially attractive due to the high data rate (54 Mb/s) and greater number of allocated channels compared to 2.4-GHz WLAN systems. However, the wide bandwidth at 5 GHz presents a challenge for RF designers, since wideband (5.15 to 5.85 GHz) antennas are more difficult to design than their narrowband 2.4-GHz counterparts. Fortunately, the authors have developed a wideband printed dipole antenna for coverage of the full 5-GHz band.

WLAN antennas are normally configured in an inverted-F (IFA) or inverted-L (ILA) form—basically a piece of metal bent into an F or L shape, respectively. However, a significant part of the antenna lies above the printed-circuit board (PCB), requiring support from foam or other materials. A more robust approach is to print it directly on the PCB, making the antenna planar and not requiring supporting foam.

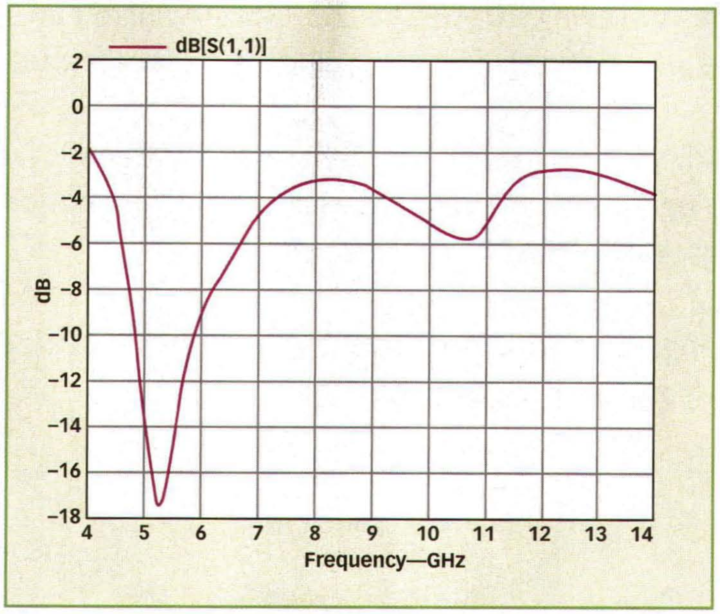
The printed dipole antenna consists of two rectangular-shaped strips, typically a quarter wavelength long. The two arms of dipole must be fed differentially. Since the front-end module preceding the antenna is typically a single-ended design, a balun will be needed to make the transformation to a differential-signal configuration. The balun for this printed dipole antenna is built on a L-shaped microstrip feed line, a viahole, and a slot. The antenna structure is shown in **Fig. 1.**



1. This dipole antenna has been printed on a low-cost FR-4 substrate. Different resonant modes can be achieved by optimizing the length and width of the slot.

The antenna is fabricated on FR-4 substrate material with a dielectric constant of 4.4 and loss tangent of 0.02 in the 5-GHz range. The dipole arms are printed on the bottom of the PCB. The length of each dipole arm is 370 mils and width is

80 mils. The L-shaped RF feed line is printed on the top of the substrate. A via-hole is used to connect the end of feed line to the right arm of the dipole. The slot is the major design parameter in this antenna design. The slot length and width are 370 and 20 mils, respectively. This structure can be easily turned upside down if it is preferred to have the dipole on top. The antenna, which is very easy to construct, provides performance that is as good as an ILA or IFA design. The impedance bandwidth is actually much wider than many ILA or IFA designs in their basic forms. **Figure 2** shows the input return loss. The impedance bandwidth of this antenna exceeds the design specification. For return loss of better than –10 dB, this antenna can easily work from 4.8 to 6.0 GHz. Since the center frequency of a printed antenna tends to shift due to many factors, including manufacturing tolerances and installation of a plastic cover, it is a good practice to include an extra guard band. In addition to its fundamental frequency range, the antenna will radiate at its second harmonics.



2. Printed-dipole input return loss is plotted here from 4 to 14 GHz.

A good way to check if the antenna is designed correctly is to observe the current distribution on the dipole arm **(Fig. 3)**. Since the two dipole arms must be fed differentially, the current phase difference at the feed point should be 180 deg. Once the current is flowing in the correct direction, the antenna's radiation pattern will behave as expected **(Fig. 4)**. The antenna has a textbook-perfect donut-shape radiation pattern, with antenna gain of 1.61 dBi.

The antenna gain can be improved by using a lower-loss (than FR-4) substrate. A lower-loss substrate, such as a polytetrafluouroethylene (PTFE), will provide improved antenna gain and efficiency, at higher cost.

The antenna structure, which exhibits an impedance bandwidth close to 1.2 GHz, offers sufficient bandwidth for 5-GHz WLANs. By optimizing the slot length and width, an additional resonant mode can be introduced for wider bandwidth at the expense of a deeper resonant notch. The printed dipole antenna was modeled with IE3D electromagnetic (EM) simulation software from Zeland Software (Fremont, CA). MRF

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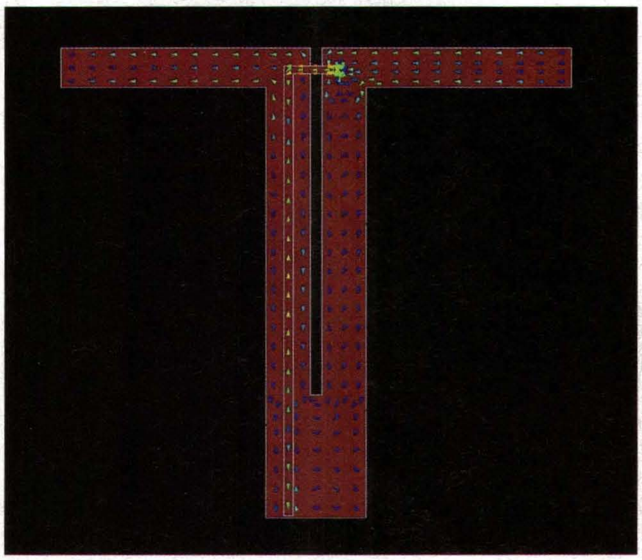
FOR FURTHER READING

1. Brian J. Edward and Daniel E. Rees, "A broadband printed dipole with integrated balun," *Microwave Journal,* May 1987.

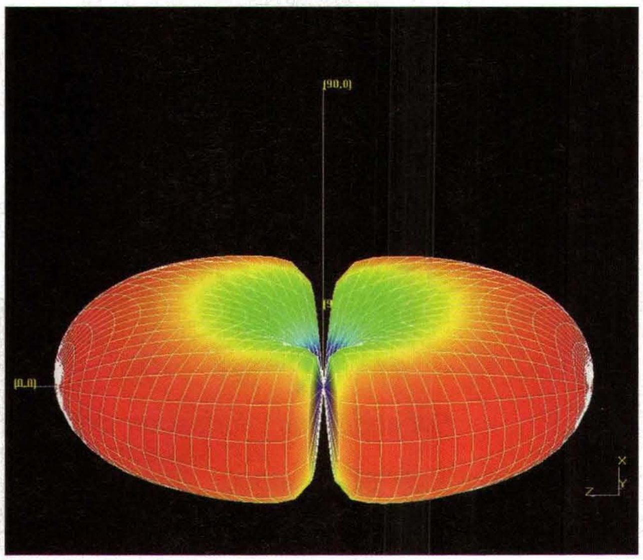
2. N. Michishita, H. Arai, M. Nakano, T. Satoh, and T. Matsuoka, "FDTD analysis for printed dipole antenna with balun," 2000 Asia-Pacific Microwave Conference.

3. S. Dey, P. Venugopalan, K. Jose, C.K. Aanandan, P. Mohanan, and K.G. Nair, "Bandwidth enhancement by flared microstrip dipole antenna," Antennas and Propagation Society International Symposium, *AP-S. Digest,* 1991.

4. G.S. Hilton, C.J. Railton, G.J. Ball, A.L. Hume, and M. Dean, "Finite-Difference Time-Domain analysis of a printed dipole antenna," *IEEE Antennas and Propagation Magazine,* April, 1995, pp. 4-7.



3. The current distribution for the printed dipole antenna was modeled with an EM simulator.



4. The radiation patterns for the printed dipole antenna were also simulated with a commercial EM software simulator.

Matching Loop Antennas To Short-Range Radios

The tapped or transformer-matched loop antenna must be properly matched to differential drives in many short-range radio designs to achieve optimum performance.

Short-range radios are invaluable wireless systems for data, telemetry, and voice communications. But to achieve optimum operation, the radio electronics must be properly matched to the antenna. Part 6 of this design series on short-range radios will address the design of tapped or transformer-matched loop antennas and show how they can best be matched to differential drives. The final installment of this multipart series will appear later this year and will cover practical issues in board design such as layout, shielding, cost control, and regulatory compliance.

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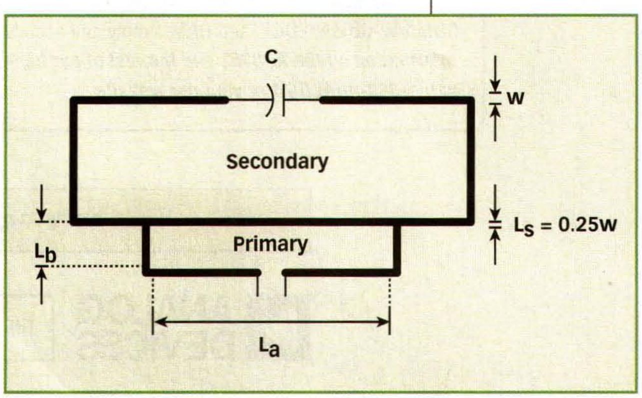
Previously, Parts 1, 2, 3, 4, and 5 of this series (see *Microwaves & RF*, September and October 2001 and February, March, and July 2002, respectively) explored short-range radio design, including link budgeting, regulatory issues, device fabrication, and loop-antenna design. Part 5 offered an introduction to loop-antenna design and the tapped-capacitor-matching method. This article will provide the basic theoretical base to understand the inductively tapped-loop antenna, which requires a lower part count than other methods, always a popular feature in the very cost-constrained short-range-radio world. A modeling method that enables understanding and design of differentially driven loop antennas is also shown. Differential drive is popular in integrated-circuit (IC) transmitters (Txs) since it aids stability in the presence of bond wire and pin inductance, provides some degree of immunity to power supply and ground noise, and can provide higher output power in the case of

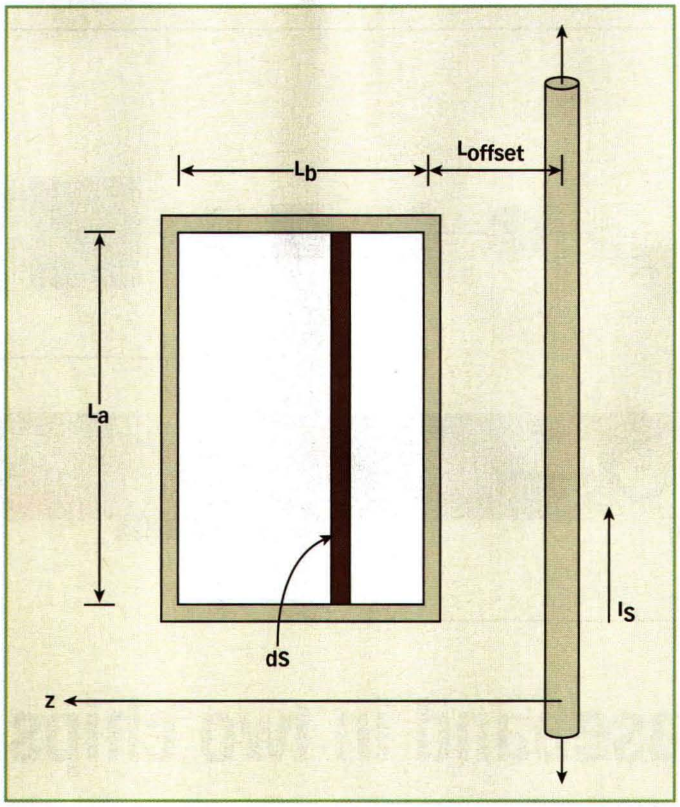


13. The typical printed-circuit-board (PCB) implementation of the transformer matched loop antenna is shown here.

some device limits.

Although the term "tapped loop" is common, this type of antenna will be referred to here as the "transformer" loop antenna in reference to what is actually its fundamental mode of operation. Understanding this matching method requires resorting to the underlying electromagnetics (EMs). Once the new model is grasped it leads directly to understanding the harmonic performance of the tapped/transformer loop antenna.

As shown in **Fig. 13,** a small loop is placed near (usually actually sharing a side with) the radiating loop antenna. The radiating loop still contains a tuning capacitor C. The two loops actually form a "loosely coupled" transformer, though there is a strong tendency among circuit designers to want to view this structure as a tapped inductor (no mutual coupling) or autotransformer (tapped inductor with mutual coupling). The correct model will be shown here to be a separated transformer, though understanding this will require a bit of an effort on the part of the reader. The transformer model seems counter-intuitive, even to experienced RF designers, since they are trained to think in lumped-component terms and not in terms of the underlying EMs upon which lumped models are based. Thus they normally conceive of a segment of trace as having complete inductance all by itself in the absence of a return path, which leads them to misinterpret Fig. 13 as a tapped inductor or autotransformer. No less an authority than Fujimoto[9] in his well-respected work on small antennas mistakenly analyzes tapped-loop antenna matching as an autotransformer, and this common error incorrectly influences the design of loop antennas to this day. The mistaken mental model has at its root the failure to understand that only closed current loops have inductance or mutual inductance. It is exacerbated by the fact that the form of transformer exhibited by Fig. 13 is not one that the engineer has encountered in his basic training—no class ever showed a separated transformer model for a situation where primary and secondary currents actually share a path segment.



14. Setting up the integration of flux density that enables calculating the mutual inductance between a closed primary and a wire secondary is illustrated here.

An open mind and a review of the underlying EMs will allow the short-range radio designer to add this important form of transformer antenna to his tool kit and gain an appreciation of the EM effects in circuits that the designer's first EMs professor probably intended. To set about developing the correct first-order understanding of this structure, the authors shall state the basic EMs upon which transformer-model argument is based with minimal explanation, leaving the reader to review their basic undergraduate e-mag text for verification. However, the authors will interpret these EMs with respect to this new situation, the loop antenna of Fig. 13, in some detail to make the model fully clear and generate the correct mental model in the reader's mind.

First consider, as background, the definition of a voltage [as electromotive force, (EMF)] as the closed line integral of electric field, which is the field form of Kirchoff's Voltage Law (KVL):

$$emf = \oint \vec{E} \bullet \vec{dL} \quad (71)$$

Next, consider the fact that electric flux through a surface is provided as the surface integral of flux density over that surface:

$$\Phi = \oint_S \vec{B} \bullet \vec{dS} \quad (72)$$

Flux is integrated up over an area—not over a line segment. Next, Faraday's Law offers voltage (EMF) as a function of flux:

$$emf = \frac{d\Phi}{dt} \quad (73)$$

Comparing Eq. 71 and 73, we note that the voltage around a loop is equal to the negative of the time derivative of flux through the loop.

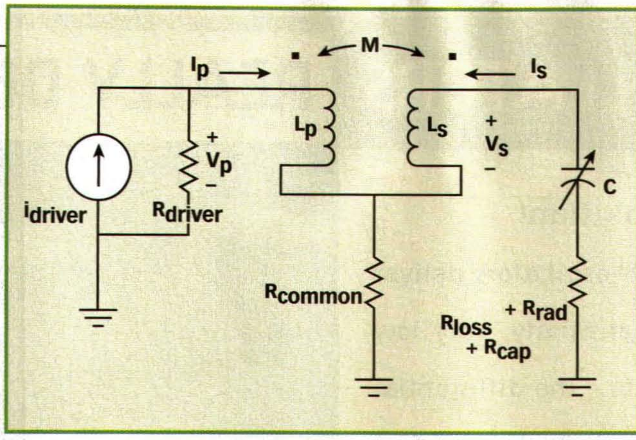
Ampere's Law gives current as the closed-line integral of magnetic field:

$$I = \oint \vec{H} \bullet \vec{dL} \quad (74)$$

Where magnetic field H is related to flux density B by:

$$\vec{B} = \mu_0 \vec{H} \quad (75)$$

When terminal voltage and current can be calculated and impedance determined as their ratio, a circuit model results. The EM equations above provide the means to determine current and voltage relationships in terms of physical geometry. Eq. 74, Ampere's Law, relates flux and current over a closed line integral that provides current con-



15. The circuit model of a transformer-matched loop antenna acts as a separated transformer with the minor exception of the shared resistance over the common section of trace.

tained within the closed-path caused by flux. From Ampere's Law, current can be found from H or B, or H and B can be found from current. When B is known, the total flux can be found from Eq. 72, and then with flux known, voltage can be found from Eq. 73. Conceptually, the full information needed for the circuit model is available, and from Eqs. 71 to 74 it can be seen that this always relies upon closed paths around current or field, and not upon a line segment. Alternately, the definitions of inductance and mutual inductance provided by Eqs. 76 and 77 can be used to make this conceptual process a bit shorter:

$$L = \frac{N\Phi}{I} \qquad (76)$$

$$M_{12} = \frac{N_2\Phi_{12}}{I_1} \qquad (77)$$

where:

N = the number of filamentary loops of current (one in Fig. 13) and

I = the current "linked" by the flux, meaning the current that surrounds the area the flux density is integrated over to get the total flux.

In Eq. 77, M_{12} is the mutual inductance where flux produced by closed (or infinite) path I_1 links current in closed or infinite path I_2. It is also true that $M_{12} = M_{21}$. Parameters L and M result in circuit equations of the form:

$$V_1 = L\frac{dI_1}{dT} + M\frac{dI_2}{dT} \qquad (78)$$

where:

V_1 = the total voltage through a self-inductance with current I_1 that is also linked to a second current I_2 sharing mutual inductance M with the current path described by I_1.

Note that in Eqs. 75 and 76 inductance cannot be calculated for a segment of line. It requires a closed path around a surface to obtain the total flux quantities as the surface integral of flux density. This is why a tapped inductor or autotransformer model of Fig. 13 is simply wrong—it does not satisfy the definition of inductance. But an integration over a closed surface, such as the primary and secondary shown in Fig. 13, gives total flux linking a closed current path, which then by Eqs. 76 and 77 allows calculation of self- and mutual inductance that enables writing circuit equations.

With the preconceived circuit-design model altered to take these fundamentals into account, it is now possible to find a correct (transformer-based) circuit model for Fig. 13. **Figure 14** shows a loop intended as the primary winding of inner dimension L_a and L_b linked by the flux generated by an infinitely long, thin, round wire. The loop is also considered to be made of thin round wire and its inner dimension is separated from the center of the infinite wire by distance L_{offset}. Of course, most antennas will be fabricated with printed-circuit-board (PCB) materials having a flat trace, but the round wire model is simpler analytically and is a good approximation of an antenna formed of circuit traces, and so is used here. Most basic EM texts go through the small exercise needed to use Ampere's Law (Eq. 74) to obtain radial H and B fields around the infinite round wire induced by current I_s in the wire. This yields:

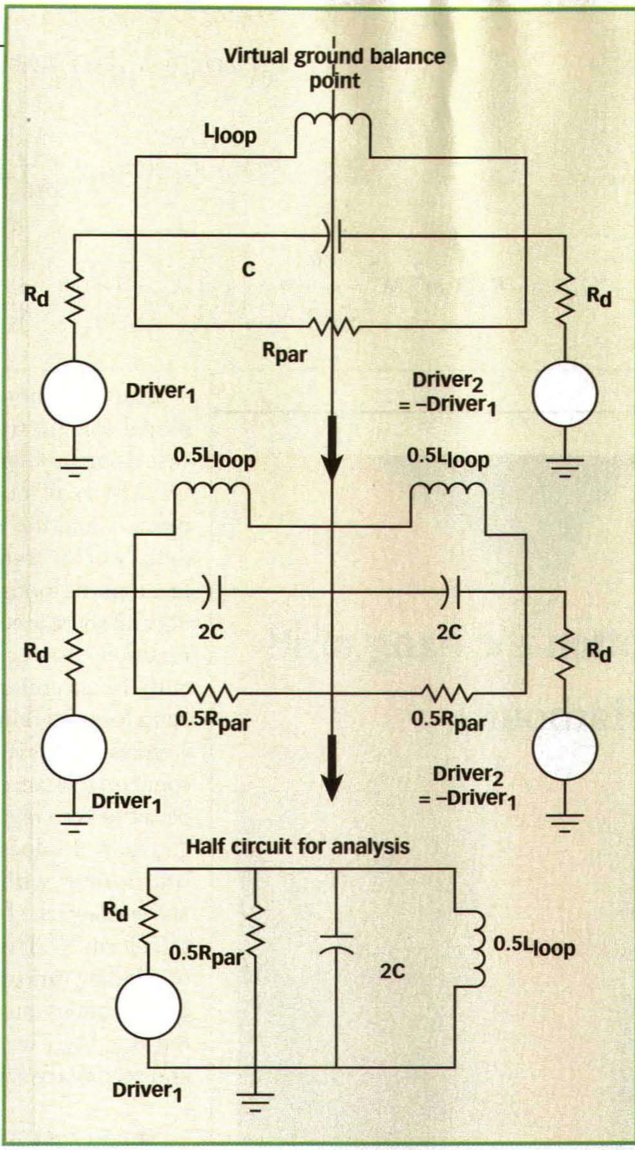
SEE EQ. 79 ON P. 79

Using Eq. 72 and the differential area element dS shown to integrate

over the area of the primary (L_a X L_b), a few lines will yield the flux, and then dividing by I_s as per Eq. 77 yields the mutual inductance:

SEE EQ. 80

Equation 80 is a useful accurate approximation (slightly large) of the mutual inductance between a small primary winding and large secondary winding, as the other sides of the secondary are much farther away from the primary winding. The separated form as shown may be used if the maximum possible mutual inductance is not needed (it will be shortly shown how impedance is controlled by mutual inductance). If maximum mutual inductance is desired, the two loops may be brought into actual contact, at which point L_{offset} will be equal to the radius of the secondary wire plus the diameter of the primary wire (not zero, which would be unacceptable in the denominator in Eq. 80). When the two loops are brought into contact, there will be no drastic change in the circuit model, which is the tricky point for most circuit designers to accept. The only effect that contact has on the model is to force the primary and secondary currents to mix in the shared segment, but this does not change the fundamental nature of the structure giving the mutual inductance which dominates the behavior. When the currents are shared in the segment, there is a small voltage induced in the primary and secondary coils due to resistance in the shared segment, not only from each on its respective side, but also from the other. For the best possible accuracy this leads to the technical need for the model to have either a single resistor in the common (to ground) terminal of primary and secondary coils, or for a "trans-resistance" to be inserted in each of the primary and secondary coils. It is critically important to note that the contact does not force



16. The half-circuit concept provides an understanding of the application of single-ended drive analysis to differentially driven loop antennas.

$$\vec{B} = \frac{\mu_0 I_s}{2\pi z} a_\phi \qquad (79)$$

$$M = \frac{\Phi}{I_s} = \frac{\mu_0 L_a}{2\pi} \ln\left(1 + \frac{L_b}{L_{offset}}\right) \qquad (80)$$

an autotransformer model. The shared segment is not an inductor, only the complete current loops of primary and secondary are true inductors. An autotransformer model would be appropriate only if a loop of primary were drawn inside the secondary.

$$I_P\left(j\omega L_P + R_P\right) + I_S j\omega M = V_P \quad (81)$$

$$I_P j\omega M + I_S\left[j\left(\omega L_S - \frac{1}{\omega C}\right) + R_S\right] = 0 \quad (82)$$

$$Z_{IN} = \left(R_P + \omega^2 M^2 \frac{R_S}{R_S^2 + X_S^2}\right) + j\left(X_P - \omega^2 M^2 \frac{R_S}{R_S^2 + X_S^2}\right) \quad (83)$$

Figure 15 shows the desired circuit model for the transformer-matching case using the concepts developed earlier. The small loop is designated as the primary and the large loop as the secondary of the transformer. Despite the fact that the loops of Fig. 13 are touching and share a side, the structure truly functions as a separated transformer with the exception that the shared side has a loss and radiation resistance that is represented as R_{common}. Normally, this common resistance is so small that it may be set to zero in calculations.

Figure 15 does not show a suitable transformer with infinite inductance and winding ratio N that yields impedance transform N^2. It is a linear transformer of winding ratio one for which full circuit equations must be written. Neglecting R_{common}, we may write primary and secondary KVL equations as:

SEE EQ. 81 ABOVE
SEE EQ. 82 ABOVE

Solving this equation set for primary voltage and current and then taking their ratio as input impedance yields:[15]

SEE EQ. 83 ABOVE

where:

Z_{IN} = the total complex input impedance,
X_P = the magnitude of the reactance of the primary,
X_S = the magnitude of the reactance of the secondary, and
M = the transfer inductance between the two loops (in Henrys).

From Eq. 83, it should be noted that when X_S is zero (secondary resonance), Z_{IN} still contains some reactance from the primary inductor impedance X_P. In practice, an extremely small amount

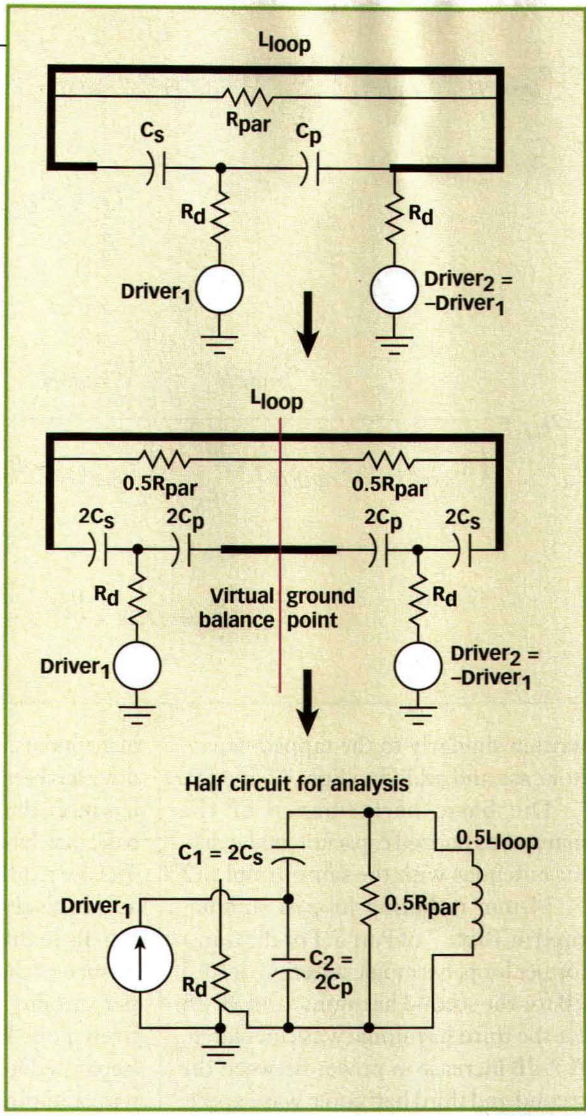
of positive (inductive) secondary reactance is required (for example, by varying the loop capacitance slightly so that secondary resonance is slightly below the operating frequency) to obtain a purely real Z_{IN}. From Eq. 83, it is possible to find that the input impedance at resonance as approximately:

SEE EQ. 84 BELOW

Equation 84 provides a simple method to match the low series resistance R_S of a resonant loop antenna to the high impedance (kohms) required by complementary-metal-oxide-semiconductor (CMOS) ICs. Initially, Eq. 84 is used to calculate the needed transfer inductance M to achieve a specific input impedance $Z_{IN} = R_D$ for matching. Secondly, using Eq. 80, L_a, L_b and offset are adjusted until the required M is achieved. Eq. 80 will generally be found to be accurate within about 10 percent, but if the greatest possible accuracy is desired, an EM simulator can be used to refine the geometry more closely. As will be seen later, to minimize radiation from the primary loop and to lower primary loop reactance, L_a should be made as large as possible, and L_b and offset should be made as small as possible.

We may now use this model of the transformer loop antenna to predict harmonic performance at frequencies where the loop is still electrically small. At harmonic "H">1, input impedance Z_{IN} (Eq. 83) simplifies to:

SEE EQ. 85 ABOVE



17. The half-circuit concept is applied to understand an efficient differentially driven tapped-capacitor loop antenna.

$$Z_{IN} \approx R_P + \omega^2 M^2 \frac{1}{R_S} \quad (84)$$

$$Z_{inH} \approx R_P + \frac{M^2}{L_S^2} \times R_S + j\omega L_P \quad (85)$$

In the transformer case, current is flowing through the primary and secondary loops. Similar to any current loop, the primary loop is an unavoidable contributor to radiation. Also, except for right around the fundamental frequency, the primary loop exhibits a broadband response with little filtering of the first few harmonics (up to the point where $j\omega L_p$ exerts a pole), unless additional filtering, such as a parallel tank circuit, is used in the driver output. The primary loop can thus dominate over the sec-

$$Z_{inH} = \left(R_{lossPH} + R_{radPH}\right)\frac{M^2}{L_S^2} \times \left(R_{lossSH} + R_{radSH} + R_{cSH}\right) + j\omega L_p \qquad (86)$$

$$\frac{P_H}{P_1} = \frac{\eta_H \, i_{rmsH}^2 \, \mathrm{Re}\left(Z_{INH}\right)}{\eta_1 \dfrac{i_{rms1}^2}{2} R_D} \qquad (87)$$

$$\eta_H = \frac{R_{radPH} + \dfrac{M^2}{L_S^2}\left(R_{radSH}\right)}{\left(R_{lossPH} + R_{radPH}\right) + \dfrac{M^2}{L_S^2} \times \left(R_{lossSH} + R_{radSH} + R_{cSH}\right)} \qquad (88)$$

$$\frac{P_H}{P_1} = 0.632 \times \frac{\eta_H}{\eta_1} \times \frac{\mathrm{Re}\left(Z_{INH}\right)}{R_D} \qquad (89)$$

ondary loop as a harmonic radiator, although if the primary area is kept as small as possible (large L_a to obtain necessary mutual inductance, small L_b to keep primary area small) it will normally fall a few decibels under the secondary loop. To calculate R_{rad} for the primary and secondary loops, Eq. 46 (Part 5) must be used for each. Then, Eq. 48 is used twice to calculate loss resistance for both loops. It is then possible to rewrite the input impedance at the harmonics in terms of the primary and secondary resistances of Eq. 85 as:

SEE EQ. 86 ABOVE RIGHT

where:

R_{lossPH} = the primary-loop-series ohmic loss at harmonic H,

R_{radPH} = the primary-loop-series radiation resistance at H,

R_{lossSH} = the secondary-loop-series loss at H,

R_{radSH} = the secondary-loop-radiation resistance at H, and

R_{cSH} = the secondary-tune-capacitor series loss at H.

Assuming that the source resistance ZD >> $j\omega L_p$, it is possible to use the real part of Eq. 86 to write the ratio of radiated harmonic power P_H to carrier power P_1 as:

SEE EQ. 87 ABOVE RIGHT

The harmonic radiation efficiency is provided by:

SEE EQ. 88 ABOVE RIGHT

Further assuming harmonic power to be 10 dB below the carrier and then adding back 5 dB for harmonic directivity, Eq. 87 can be reduced to:

SEE EQ. 89 ABOVE RIGHT

If ZD is not much greater than $j\omega L_p$, then a current divider function may be written similarly to the tapped-capacitor case and added to Eqs. 87 and 89.

The basic performance of the unmatched, tapped capacitor, and inductor antennas with the same sample 12 × 34-mm radiating loop is summarized in Table 7 of Part 5. For the transformer loop, harmonic rejection of 41.5 dB for the second harmonic and 36 dB for the third harmonic was calculated. A 7-dB increase in power between the second and third harmonic was expected due to radiation resistance being a fourth-order function of frequency as in Eq. 45. It is important to note that the harmonic rejection of the transformer-loop antenna is not based on parallel inductive capacitive (LC) filtering, but on extreme mismatching at the harmonic frequency. The loop capacitor brings about the resonance condition in cooperation with the mutual inductance of the transformer, which leads to a good match at the fundamental frequency. Away from the fundamental frequency, this match is not supported and the input impedance of the primary is extremely small, so that i^2R radiated power is also small.

Differential Drivers

Most discrete short-range Tx designs use a single-ended RF output port based on a discrete transistor and are easy to visualize in terms of a driver model referenced to the same ground as RF test instruments. As a result, a single-ended drive has been used in these analyses since it is more illustrative in introducing the basic matching forms. But most integrated Txs use a differential output that is not as intuitively clear. The desire to carry signals in differential mode is a consequence of the need to maintain amplifier stability in the presence of a relatively poor RF ground inside the chip (separated from board ground by bond wire and pin inductances), the need to maintain power supply, ground common-mode noise rejection (the RF circuitry is very close to the digital control circuitry in an integrated Tx), and the convenience of matched devices on the semiconductor die that can meet these needs. A secondary benefit is the extra transmit power that can be provided if voltage swing limits with a single device are the limiting power factor.

The easiest way to visualize differential drivers with a loop antenna is to use the "half-circuit concept" depicted in **Fig. 16.** This concept is based on acknowledging the fact that the drivers are matched but have voltage outputs that are 180 deg. out of phase. This results in points on the circuit where the voltage does not swing relative to ground and these points can be viewed as artificial grounds. This makes it possible to consider the full antenna as consisting of two half circuits that are each driven single ended, and that each remain resonant at the desired frequency with

one-half the inductance and resistance, and twice the capacitance of the full circuit. Each half circuit also maintains the same quality factor(Q).

It is not necessary to maintain a perfect geometric balance in a loop antenna to use differential drive. To reduce components parts may be combined. This may result in loop antennas whose functionality is not apparent at a glance, but by breaking the parts back up into the symmetric circuit needed for half-circuit visualization the operation and matching will become clear. For example, the circuit in **Fig. 17** that at first appears to have no matching is seen to actually be the excellent tapped-capacitor form, though highly efficiently implemented with only two physical capacitors.

The authors believe that transformer model of the loop antenna presented here has not been published previously, with the exception of our own recent application note, and that this method for the first time provides a correct basic model of the tapped-loop antenna. Here the circuit designer's intuition can lead to erroneous conclusions and reversion to the underlying EMs is required. Based on the terminal behavior of the loop antenna and its behavior over the first few harmonics where the loop is still electrically small, the relations provided should support approximate prediction of radiated harmonics. However, one often finds that a particular board layout does not meet the predicted harmonic suppression. This is probably most often due to unsuitable effects in the layout, such as harmonic leakage onto power lines that then radiate above the level of the loop. However, it is sometimes due to effects related to the antenna no longer being electrically small. Dealing with these effects falls into the realm of advanced analysis and EM simulation.

The seventh article in this series on short-range radios, to be published this fall, will present detailed practical board-level results with single-ended and differential drivers, and design suggestions for achieving the maximum output power and minimum harmonics at the least cost with practical components and PCB layout methods. These results will be related to the key issue of meeting regulatory requirements. The basics of making approximate engineering laboratory measurements to confirm regulatory compliance will also be reviewed. MRF

FOR FURTHER READING

14. Jan van Niekerk, *Application Note AN831: Matching Small Loop Antennas to rfPIC™ Devices*, Microchip Technology, Inc., Chandler, AZ, 2002.

15. W. Hayt and J. Kemmerly, *Engineering Circuit Analysis*, 3rd ed., McGraw-Hill, New York, 1978.

16. W. Hayt, *Engineering Electromagnetics*, 4th ed., McGraw-Hill, New York, 1981.

New Methods Debug Wireless Protocols

Using the proper tools, comprehensive analysis of wireless protocol software is critical to the design and development of a successful wireless product.

Development of a wireless product can be a daunting task, especially considering the complexity of the protocol software stack. Fortunately, by understanding the details of protocol software analysis and how to use a modern protocol analyzer, time to market can be reduced and production obstacles can be removed. Wireless systems have grown in complexity. For example, a typical specification for a first-generation (1G) system using analog transmission requires 400 pages. Global System for Mobile Communications (GSM), the first of the digital second-generation (2G) systems, has approximately 4000 pages in its standard. Wideband code-division multiple access (WCDMA), the most complex of the third-generation (3G) systems, is now more than 28,000 pages and still growing.

In the face of this complexity is increased pressure for time to market. The original GSM rollout took approximately five years between adoption of

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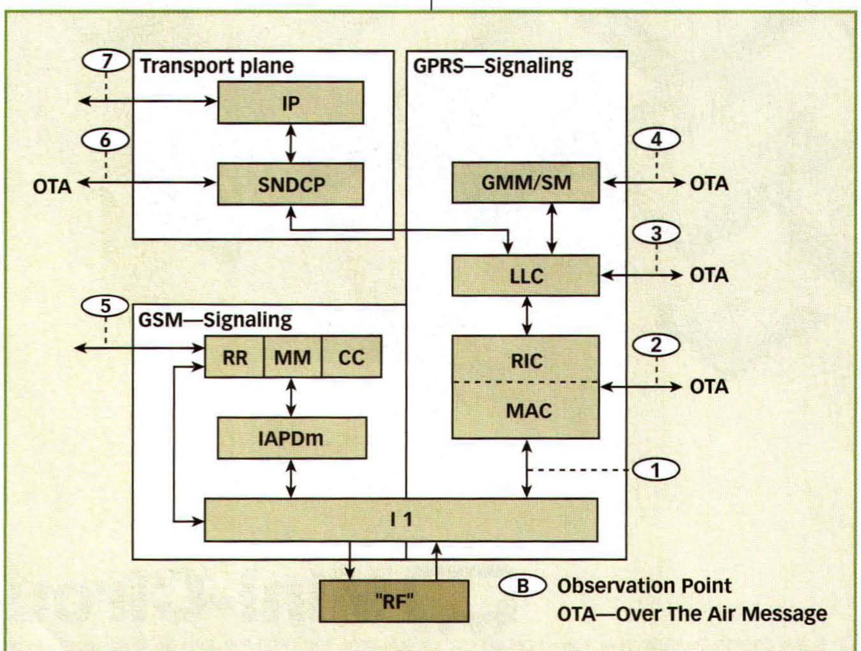
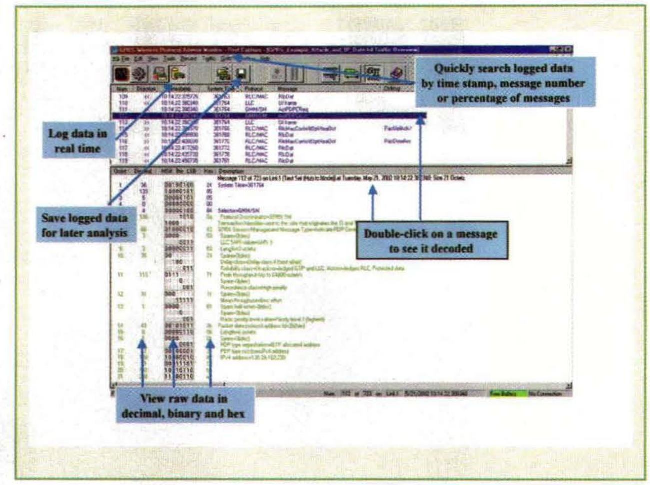


1. In this GPRS protocol stack, the lower left block is the is the control stack used to initiate calls or packet transfer, the right block manages packet-data flow as well as the handset control while in a link, and the upper left block is the data application.



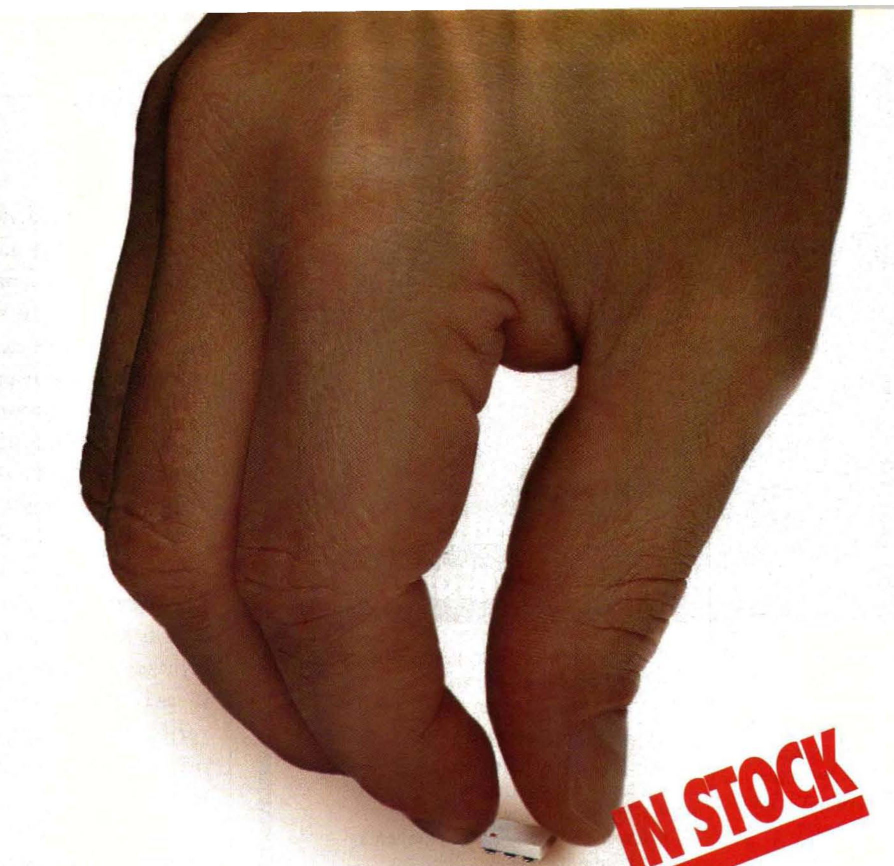
2. This sample display of a protocol log shows a high-level view in the upper window and a detailed view in the lower window.

the standards and commercial operation. WCDMA was first adopted in December 1999, but it can be argued that this version was a prerelease, and the real release did not occur until June 2000. Every attempt is being made to provide commercial service in 2003, but this date is not certain.

The development of a wireless handset goes through many phases **(Table 1)**. While there is considerable overlap of these phases, each has its unique requirements and style. The phases generally are design, implementation, and integration. The design phase is where make-or-buy decisions are made. The exact requirements of the handset are developed, along with the target feature set. Many times, a family of handsets is really being designed with software options that deliver variations in feature set.

The implementation phase is where printed-circuit boards (PCBs) are designed, plastic housings and internal shielding are developed, and the unique/new software is developed. The integration phase is when all the pieces come together. Final software verification cannot occur until integration, ensuring that this will eventually be the critical path of design release. RF performance is checked over the full dynamic range of operation, level and frequency. It is during this phase that the different software functions are fully integrated in the target environment. While much integration work is performed before realizing the full design, it is difficult to fully debug the software in a simulated environment, so it is almost a certainty that the final debugging of the software will set the schedule for release to manufacturing. There are many elements to this software. These include the user interface and handset control, air-link protocols, web-browser function, input/output (I/O) connections to external devices, and measurements of the operating environment. It is also during this phase that the full performance of the handset is verified.

One aspect that substantially raises the complexity of the protocol software is the support of packet-data transmissions. In a packet-switched network, the system resources are not



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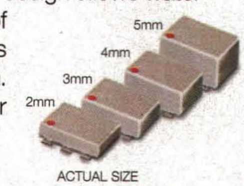

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ADE-1	+7	0.5-500	5.0	55	15	4	1.99▲
ADE-1ASK	+7	2-600	5.3	50	16	3	3.95
ADE-2ASK	+7	1-1000	5.4	45	12	3	4.25
ADE-6	+7	0.05-250	4.6	40	10	5	4.95
ADEX-10	+7	10-1000	6.8	60	16	3	2.95
ADE-12	+7	50-1000	7.0	35	17	2	2.95
ADE-4	+7	200-1000	6.8	53	15	3	4.25
ADE-14	+7	800-1000	7.4	32	17	2	3.25
ADE-901	+7	800-1000	5.9	32	13	3	2.95
ADE-5	+7	5-1500	6.6	40	15	3	3.45
ADE-5X	+7	5-1500	6.2	33	8	3	2.95
ADE-13	+7	50-1600	8.1	40	11	2	3.10
ADE-11X	+7	10-2000	7.1	36	9	3	1.99▲
ADE-20	+7	1500-2000	5.4	31	14	3	4.95
ADE-18	+7	1700-2500	4.9	27	10	3	3.45
ADE-3GL	+7	2100-2600	6.0	34	17	2	4.95
ADE-3G	+7	2300-2700	5.6	36	13	3	3.45
ADE-28	+7	1500-2800	5.1	30	8	3	5.95
ADE-30	+7	200-3000	4.5	35	14	3	6.95
ADE-32	+7	2500-3200	5.4	29	15	3	6.95
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ADE-1H	+17	0.5-500	5.3	52	23	4	4.95
ADE-1HW	+17	5-750	6.0	48	26	3	6.45
ADEX-10H	+17	10-1000	7.0	55	22	3	3.45
ADE-10H	+17	400-1000	7.0	39	30	3	7.95
ADE-12H	+17	500-1200	6.7	34	28	3	8.95
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assigned to an individual user until they are needed for actual transmission of a packet or group of packets. Immediately after the transmission, the system resources are released from this one user and become available for use by other users. The amount of system messages increases substantially from circuit-switched systems, due to the dynamic assignment and release of these resources.

An additional area of increased complexity in the handset is the addition of a browser to the handset environment. While most manufacturers buy the browser function from an outside party, there is still substantial integration and verification testing needed. The most prevalent test method currently uses test equipment that is capable of running a script. The script is the exact sequence of message interchange needed to implement a specific feature. GSM, General Packet Radio Service (GPRS), and WCDMA all have test suites developed as part of the minimum performance standards. A scripting machine emulates a network, with the downlink messages generated from the scripting environment. The response from the handset is checked bit by bit against the script for expected uplink operation. Alternative implementations in the handset are rejected by this system, even though the approach may be fully compliant with the air-interface standard. A tool has been selected to assist in the generation and execution of the script, known as Tree and Tabular Concatenated Notation (TTCN). This is typically an application that may be run on a workstation. Script-based test solutions are usually very large and very expensive and require a trained operator who can develop the new test suites. A developer takes the handset to the test equipment for testing.

The development of a wireless handset goes through many phases—design, implementation, and integration.

Table 1: Tracking the development phases of a wireless handset

Design	Implement	Integrate
Make or buy	RF layout	Confirm RF specs
Define features	Software written and simulated	Evaluate protocols and applications
Package design	Hardware tooling	Manufacturing process conformance

The suites written for conformance testing of GSM, GPRS, and WCDMA (in progress) contain approximately 300, 400, and 700 test cases, respectively. Vendors of handsets often augment this test environment with many hundreds of additional test cases. Development takes two weeks to three months depending on the complexity of the scenario and the knowledge level of the operator. These test systems are frequently heavily used and engineers are often required to work odd hours to verify their designs. One vendor reports using 1200 cases for GPRS and points out that there is still the requirement to test against real network equipment to verify interoperability.

An alternate test method is to use test equipment that has an active protocol stack. This equipment more closely emulates a real network since networks use protocol stacks. No test suites are required, and the equipment does not require a trained operator. However, the range of testing is limited to only those features implemented in the stack. This equipment is less expensive, and is well-suited to put on an engineer's bench. Test capacity problems are eased because more equipment can be purchased. No specific training is needed for operation. As with script-based equipment, use of this type of testing will not entirely eliminate interoperability testing. **Table 2** summarizes the characteristics of script- and stack-based equipment.

Particularly useful with either type of test equipment is the ability to monitor the exact messages sent to and from the handset in an organized list. The network structure is organized into layers, according to the International Standards Operation (ISO) seven-layer Open Systems Interconnect (OSI) model. Within this model, different layers of the protocol stack have different functions. The physical layer, or layer one, is the link. Layer two monitors link integrity, packet by packet, typically by checking error detectors [usually a cyclical redundancy check (CRC)] appended to each packet. Requests for retransmission of lost packets and the retransmission itself are examples of layer-two operations at a receiver (Rx) and transmitter (Tx). Layer three is generally considered the control layer. This is where a message is sent to perform a handover, or adjust power. In wireless systems, there are generally two parallel stacks, one for the control functions, and one for the flow of the user data itself.

The general rule is that any layer in the handset can only talk directly to the equivalent layer of the network, and vice versa. So, while the only real link is

Table 2: Comparing Script-based and Stack-based protocol test equipment

	Scripting	Stack
Message coverage	Complete possible	Limited
Ease of use	Difficult: weeks to months	Moderate: minutes to hours
Data at high speed?	No	Yes
Connect to Internet?	Yes, but at low speeds	Yes
Price	High: $300k to $2M	Moderate: $50k to $150k

at layer one, there is a virtual link of each layer and sublayer. Generally, the rules of operation between sender and receiver for any one layer constitute a single standard. The collection of these standards define overall operation of a system. In practice, the software for each layer may be implemented by different design engineers, and executed as separate processes in a multi-tasking computer environment. There is great need for evaluation tools in this environment.

One useful tool is the protocol analyzer. This is similar to an oscilloscope for protocols. While an oscilloscope looks at signals or waveforms as a function of time, the protocol analyzer looks at messages as a function of time. An oscilloscope may have multiple probes, which may be attached to numerous locations of a circuit. The protocol analyzer also has many probes, typically one for each layer in the system. The output may not be as glamorous as waveform displays, but they are equally important to the engineer who writes the protocol software. The protocol examples provided are from GPRS, the first packet system that appears to have critical mass to be commercially viable. The concepts are equally applicable to cdma2000 and WCDMA.

Figure 1 shows the protocol stacks for GPRS. This is a symmetric system, as are most wireless systems. This stack represents either the network or the handset, and an equivalent stack operates the other half of the link. Generally, it is important to monitor messages at any layer in the stack. The acronyms are not so important here, but the layered structure is shown. The probe locations are identified as observation points.

Embedded software is a major element of modern handset design, and air-link protocols constitute the major portion of this software.

One of the most interesting probe locations for packet data is the radio-link-control/medium-access-control (RLC/MAC) layer. The purpose of this layer is to control data flow and assure each packet is correctly received. One requirement of RLC is in the area of memory. On the transmit side, sent packets must be retained in memory for a prescribed period of time to support a request for retransmission from the Rx should the packet get lost in transmission. On the Rx side, the memory requirement is to keep packets around so that a retransmitted packet may be placed in its prop-

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er place in sequence. As data rates increase, the packet sizes generally also increase. The ramification of this is that the memory requirements in a handset scale roughly with the maximum data rate. As memory is one of the more expensive hardware elements in the handset, the maximum data rate is carefully matched to expected service levels of the operators.

As an example of the complexity of these protocols, a log was generated where a GPRS handset was first turned on, where it went through normal procedures to attach to the system. Following that, a short web page was requested from the handset. Since this was to demonstrate the overhead of a packet-switched system, the message count was stopped when the actual traffic channel was assigned to start the packet transfer. In this example, there were 135 messages exchanged to get the handset into the attached state, followed by 27 messages ending with the assignment to a traffic channel where the actual web data could be transmitted. A sample protocol log is shown in **Fig. 2**.

It is important that test environments mimic real-use environments as much as is practical. To this end, new connectivity has been added to the test environment. Rather than attempt to generate every type of web application inside the test equipment, a network port is added, with linkage between this port and the air link. The test equipment acts as the transducer between the handset and the Internet. With this setup, any application available on the Internet can be presented to the handset. Of course, a local computer may be used to emulate the Internet, in whole or in part. One often-tested application is the maximum speed the handset will support. Typically, this is tested with a local computer acting as the Internet, and an File Transfer Protocol (FTP) data delivery using several sizes of files to a local computer attached to the handset. In practice, this can be the same computer as the data source.

Another example of a test is in the area of interactive gaming. Often, this will involve animations on the handset's screen. It may be desirable to see the effect of data rate on this operation. Data rate can be adjusted in many ways. The obvious method is to adjust the transmission structure to change the rate over the air. A second method is to set the link at its limit of operation in the presence of noise. A desired packet-error rate can be set, and the effects of latency in the data transmission can be evaluated. This type of testing is applicable to any type of software that allows for user interaction on a handset's screen. Other examples are short-message service (SMS), web browsers, and e-mail.

Embedded software is a major element of modern handset design, and air-link protocols constitute the major portion of this software. The complexity of the air interface continues to grow, as does the feature set and the required validation. Having the right tools can transform the way design engineers do their job. Agilent Technologies (Santa Clara, CA) has added protocol analysis for GPRS and cdma2000 to the Agilent E5515C one-box test set. It is anticipated that this test capability for WCDMA will also be added soon. MRF

BOOK*mark*

The Essential Guide to RF and Wireless, 2nd Ed.

CARL. J. WEISMAN

WIRELESS TECHNOLOGY HAS run rampant over most people's lives, in the forms of their cordless telephones, pagers, cellular telephones, and other "convenience" devices. Most of the engineering readers of this magazine are well-versed in the many different technologies associated with wireless design. But what about those who are not engineers, who must work with engineers in marketing, sales, and support positions, and who need to know more about wireless technology but fear the theory and the mathematics. For them, there is the second edition of *The Essential Guide to RF and Wireless* by Carl J. Weisman.

Part 1 covers engineering fundamentals, including the nature of RF signals, transmitters (Txs) and receivers (Rxs), signal loss and attenuation, definitions for decibels and bandwidth, and the meaning of impedance matching. Part 2 highlights hardware, describing the basic functions of antennas, amplifiers, filters, mixers, signal sources, switches, attenuators, dividers/combiners, couplers, circulators/isolators, transformers, detectors, phase shifters, and phase detectors. Additional sections in Part 2 explore transistors, diodes, and integrated circuits (ICs).

Part 3 is devoted to "RF Systems" and essentially details different RF and microwave applications, including those defined as "older technologies," such as broadcasting, radar systems, satellite communications, and point-to-point microwave links; "newer technologies" such as the mobile telephony embodied in cellular and Personal Communications Services (PCS) systems; and what the author calls the "new world of wireless" in the form of broadband fixed wireless applications, wireless networks, the mobile Internet, and a section called "the Bleeding Edge." The "Bleeding Edge" section briefly describes ultra-wideband (UWB), microelectromechanical systems (MEMS), time-hopping-spread-spectrum (THSS), Bell Labs Layered Space-Time (BLAST), and other RF technologies that are only starting to find toeholds in wireless applications.

The Essential Guide to RF and Wireless may seem overly simplistic to most practicing electrical engineers, but is really not meant for that audience. For sales and marketing professionals who must learn more about wireless technologies and applications, however, this is a useful guide to a wide range of RF application areas, written in a lively and accessible format. (2002, 311 pp., softbound, ISBN: 0-13-035465-1, $34.99.) **Prentice Hall, One Lake St., Upper Saddle River, NJ 07458; (800) 382-3419, FAX: (201) 236-7141, e-mail: corpsales@prenhall.com.**

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Determine hot spots of different structures

THE QUESTION OF heat flow is usually determined by electrical engineers during their training in physics and later as in-field problems. Heat flows through radiation mechanisms known as convection and conduction, both of which have their own sets of coefficients and equations. But how much power can a microwave device handle before it overheats? A two-page application note, entitled "Thermal Resistivity Table Simplifies Temperature Calculations" from KDI/Triangle Corp. (Whippany, NJ), attempts to provide a decent approximation of the unique and determining hot spots of different structures.

This subject is made all the more confusing by the use of c.g.s. units in physics and British Thermal Units (BTUs) in engineering. The requirement of determining how hot a particular point in a structure will become when power is being dissipated provides the catalyst of many significant temperature calculations performed by engineers. Heat sinks may dispel energy through free or forced convection to air or liquid, but the internal circuit elements, whose temperature rises usually set a limit on power-handling capability, are cooled by conduction much of the time. Radiation below 300°C plays a largely insignificant role.

Temperature-rise estimates in conduction-heat-flow cases are easily calculated, because the steady-state Fourier heat-flow equation is the mathematical equivalent of Ohms Law for electrical circuits, only with temperature differences replacing voltage differences and heat flow replacing current flow. If one prepares a thermal-resistivity table in units of Celsius degrees minus inches per watt for the materials that are experienced in microwave operations, temperature drops can be estimated in series heat-conduction situations. Two examples of these concepts, one featuring a thin-film resistor within a microwave integrated circuit (IC), and another with a miniature rod resistor terminating a coaxial line, are included.This application note is available as a free download from the company's website.

KDI/Triangle Corp., 60 South Jefferson Rd., Whippany, NJ 07981; (973) 887-8100, FAX: (973) 884-0445, e-mail: kdisales@aol.com, Internet: www.kditriangle.com.

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Along with installing base stations in new locations, multiple modulation standards are also being introduced...overlaying and overlapping older standards.

Learn about an MMIC amplifier for base stations

TO SUPPORT THE worldwide growth of wireless subscribers, new base-station installations must grow as well. Much of the the wireless growth is expected to use linear-modulation formats along with Global System for Mobile Communications (GSM). Along with installing base stations in new locations, multiple modulation standards are also being introduced into existing areas, overlaying and overlapping older standards. As a reaction to this, new base-station amplifiers have been designed to be smaller, lower in cost, and more manufacturable, so components with a higher level of integration that offer automated, surface-mount-assembly (SMA) capabilities are preferred.

In a six-page application note entitled "A High-Power, Class-AB, MMIC Amplifier for Base Stations" from Anadigics, Inc. (Warren, NJ), authors Sergei Kent, Richard Frey, and David Osika present model AWT921S11, a gallium-arsenide (GaAs)-based monolithic-microwave integrated circuit (MMIC) for use in base stations and other fixed terminals. The authors describe design considerations, chip design, packaging, and performance.

The electrical parameters for the MMIC include operation over the 800-to-1000-MHz frequency range with an input return loss of 10 dB. Quiescent current is 400 mA and supply voltage is +8.5 VDC. Reliability is greater than 10^6 hours and operating temperature is –30 to +85°C. Saturated performance includes output power of +39 dBm, power gain of 30 dB, and power-added efficiency (PAE) of greater than 40 percent. Linear performance features power gain of 30 dB and PAE of greater than 30 percent. The unit is housed in a 300-mil small-shrink outline package (SSOP). Overall thermal resistance is 6 C/W and bias-circuit requirements are ±5 VDC nominal. This note is available as a free download from the company's website.

Anadigics, Inc., 35 Technology Dr., Warren, NJ 07059; (908) 668-5000, FAX: (908) 668-5068, e-mail: sales@anadigics.com, Internet: www.anadigics.com.

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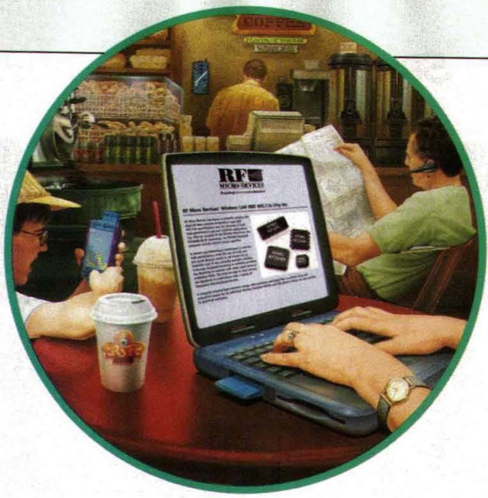

Chip Set Offers Compact 2.4-GHz WLAN Solution

This four-piece IC set blends semiconductor processes to achieve the smallest, lowest-power solution for developers of IEEE 802.11b WLAN products.

BILL RHYNE
Marketing Manager of Wireless LAN Products
RF Micro Devices, 7628 Thorndike Rd., Greensboro, NC 27409; (336) 664-1233, FAX: (336) 931-7454, Internet: www.rfmd.com.

Wireless local-area networks (WLANs) represent one of the fastest-growing market segments of the wireless industry. Based on various sets of IEEE standards, WLANs offer access to high-data-rate, two-way communications, without the restrictions of Ethernet cables. In support of this growing marketplace, RF Micro Devices (RFMD; Greensboro, NC) has developed a complete chip set that meets the requirements of the IEEE 802.11b WLAN standard.

The chip set consists of the RF2494 low-noise amplifier (LNA)/mixer, the RF2948B RF/intermediate-frequency (IF) transceiver, the RF5117 (transmit) power amplifier (PA), and the newly announced RF3000 baseband processor. The WLAN chip set complements the company's capabilities in other wireless areas, including Bluetooth, cellular handsets [such as the Polaris Total Radio transceiver integrated circuit (IC) for General Packet Radio Service (GPRS) and Enhanced Data rates for Global Evolution (EDGE)], and Global Positioning System (GPS) ICs, allowing customers to design multifunction products in small package sizes and, as important, with fewer interconnections and fewer passive components. As wireless solutions evolve, they must consume lower power than solutions from previous generations. However, lower power must not be achieved by sac-

rificing performance. While consumers are demanding greater functionality and smaller products, they will not tolerate a reduction in performance. Finally, there is an expectation from the market that prices will drop at a continuing pace. Thus, RF IC providers strive to provide new solutions that are smaller, use less power, provide greater functionality, and offer increased performance—all at a lower price.

The new WLAN chip set is a complete WLAN physical-layer solution designed to meet IEEE 802.11b specifications and the demands of high-performance and cost-sensitive applications. The RF2948B 2.4-GHz spread-spectrum transceiver includes a quadrature demodulator, a quadrature-phase-shift-keying (QPSK) modulator and upconverter, programmable baseband filters, and a sensitive receiver (Rx) with variable-gain control. The receiver portion has a nominal frequency range of 45 to 500 MHz with as much as 76 dB cascaded voltage gain. The cascaded noise figure ranges from 5.5 to 35 dB. The transceiver, which is designed for maximum RF input level of +12 dBm and local oscillator (LO) drive levels as high as +5 dBm, is supplied in a 32-pin, leadless chip carrier (LCC) measuring 5 × 5 mm.

The WLAN solution uses a proven superheterodyne architecture for high performance. This approach requires a surface-acoustic-wave (SAW) filter at IF. The price of SAW filters continues to decline, bringing the costs of the superheterodyne and direct-conversion architecture into parity. Typical direct-conversion approaches to WLAN systems require one or two baluns, which may be similar in price to a single SAW filter. The four-chip solution is the lowest-priced physical-layer solution in production today.

But performance cannot be sacrificed in the interest of cost. Consumers expect the level of performance to be maintained or increased with a con-

The new WLAN chip set, which includes a transceiver, LNA/mixer, and baseband processor, is a complete WLAN physical-layer solution designed to meet IEEE 802.11b specifications and the demands of high-performance and cost-sensitive applications.

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tinued decrease in cost. The superheterodyne approach is used in today's highest-performing solutions and results in a typical receive sensitivity of –85 dBm at 11 Mb/s in the company's reference designs. Comparable sensitivities are difficult to achieve with direct-conversion architectures.

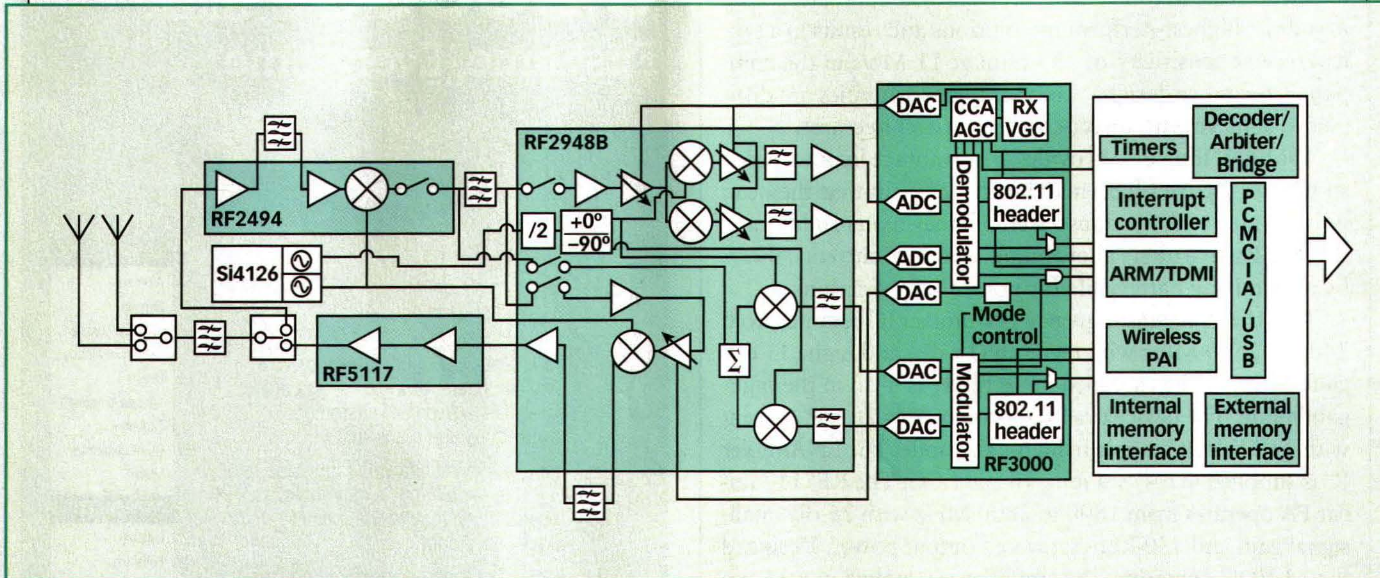
The SAW filter also provides an advantage in power consumption. Active filters may be attractive in that they can be integrated with the transceiver, but they require additional current. Passive filters allow minimal receive currents, thereby maximizing battery life for portable applications.

The RF2494 high-frequency LNA/mixer IC operates from 2400 to 2500 MHz with medium (19-dB) and high (35-dB) gain settings. The cascaded noise figure is 4 dB in the high-gain mode. The device draws approximately 20-mA current with a +2.7-VDC supply in high-gain mode. The LNA/mixer IC is supplied in a 4 × 4 mm, 16-pin LCC. The RF5117 linear PA operates from 1800 to 2800 MHz with 26-dB small-signal gain and +30-dBm saturated output power. Designed for +3-VDC operation, the amplifier is supplied in a 16-pin LCC measuring only 3 × 3 mm.

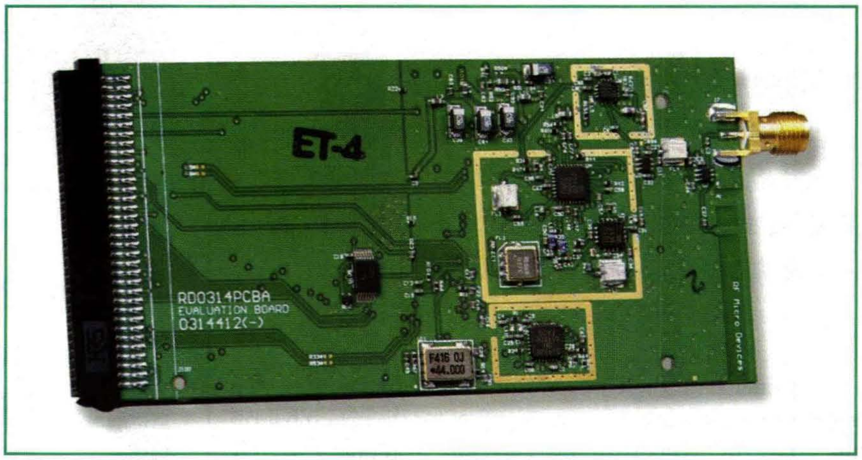
Together with the baseband processor, the WLAN chip set features small, low-pin-count devices for the bill-of-materials (BOM) cost of any currently available 2.4-GHz WLAN solution.

Together with the baseband processor, the WLAN chip set features small, low-pin-count devices for the lowest bill-of-materials (BOM) cost of any currently available 2.4-GHz WLAN solution. The RF3000 is a discrete baseband processor that provides the flexibility to operate with either standalone or embedded media-access-controllers (MACs). The chip set may be used without the baseband in combination with a variety of integrated MAC/baseband devices. Providing the user with a choice of MAC solutions allows the user to select the MAC that provides the most benefits for the application under consideration.

By using their Optimum Technology Matching™ strategy, engineers from RFMD are able to match the appropriate process technology to device requirements. For example, the RF2494 LNA/mixer and the RF2948B RF/IF transceiver are manufactured using silicon (Si) bipolar-complementary-metal-oxide-semiconductor (BiCMOS) process technology. The RF3000 baseband processor is manufactured using Si CMOS process technology and packs an advanced equalizer into a small 28-pin package. The interface is compatible with several MACs, providing the user with the option of choosing the MAC that is most appropriate for the application. To meet demanding user requirements, the



1. The RFMD IEEE 802.11b system block diagram is shown here.



2. The RFMD physical-layer solution reference design is illustrated here.

RF5117 PA is manufactured using gallium-arsenide (GaAs) heterojunction bipolar transistor (HBT)—a process technology that produces highly efficient linear amplifiers capable of delivering the maximum allowable output power with high efficiency and greater margin to meet spectral mask requirements. The RF5117 PA is designed to operate from a single +3.3-VDC supply but it may be used in +3- and +5-VDC applications, making it appropriate for client devices as well as access points (APs). The RF5117 delivers +22 dBm typical linear output power from 1800 to 2800 MHz when operating with a +3-VDC supply and +27 dBm typical linear output power when operating from a +5-VDC supply. The small-signal gain is typically 26 dB and isolation in the off state is typically 45 dB. The amplifier is supplied in a 16-pin LCC housing.

The WLAN chip set forms a major portion of a complete IEEE 802.11b physical-layer solution **(Fig. 1)**. The chip set is supported by several reference designs, with or without the MAC chip. A model RD0314 physical-layer reference design is also available **(Fig. 2)**, complete with schematic diagrams, layout drawings, and BOM. In addition, complete Personal Computer Memory Card International Association (PCMCIA) [DK0312] and Universal Serial Bus (USB) [DK0313] design kits are available to qualified customers.

One of the key metrics and enablers for the concept of convergence is cost. While the trend is for higher integration and fewer numbers of ICs, integration alone does not lead to lower costs. A better metric for cost may be the number of interconnect pins used by a packaged IC. Package pin count translates into cost in three ways: package cost, die cost, and passive-component cost. The four-chip WLAN solution from RFMD features small, low-pin-count devices. The low pin count supports a WLAN solution that features a high degree of flexibility at low cost.

This first-generation 2.4-GHz WLAN chip-set solution offers outstanding performance and is the lowest-cost solution available. A second-generation chip set will be available in the future and will offer a significant reduction in the power consumption, size, and BOM cost compared to competitive alternatives, while maintaining the high level of performance of the existing solution. The 2.4-GHz WLAN chip set is available now in high-volume production and is the basis for a number of enterprise and consumer products found in the marketplace today. **RF Micro Devices, 7628 Thorndike Rd., Greensboro, NC 27409; (336) 664-1233, FAX: (336) 931-7454, Internet: www.rfmd.com.**

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Modular Synthesizers Shave Phase Noise

Available as narrowband and wideband models, these frequency synthesizers boast high-frequency resolution, low spurious content, and generous output power.

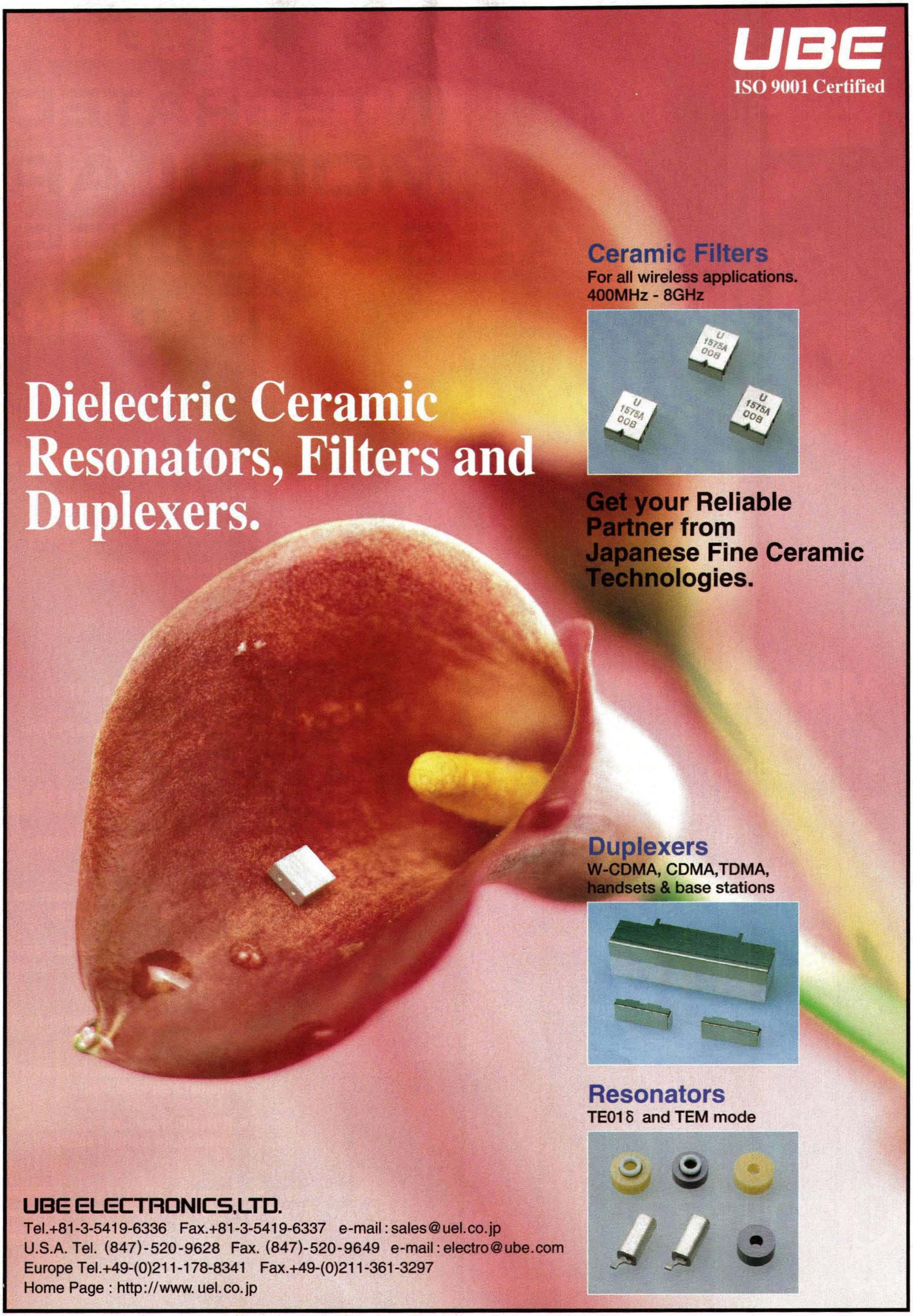
JACK BROWNE
Publisher/Editor

Modular frequency synthesizers are one of the more complex of RF/microwave building blocks for a receiver (Rx) or measurement system. Fortunately, the engineers at Micro Lambda Wireless, Inc. (Fremont, CA) have developed "plug-in" synthesizer solutions that suit narrowband and wideband requirements in satellite-communications (SATCOM), telecommunications, and test applications. The company's wideband MLSW series of synthesizers is available from 0.6 to 10 GHz, while the narrowband MLSN series covers 2-GHz bands from 2 to 10 GHz. The synthesizer lines share impressive phase-noise performance, 1-Hz frequency resolution, and low spurious content.

Broadband MLSW series synthesizers **(see figure)** are suitable for use as the main local oscillator (LO) in receiving systems, test equipment, and for general frequency-conversion applications. Models are available for coverage of 0.6 to 3.0 GHz, 2 to 8 GHz, and 2 to 10 GHz. Model MLSW-2010, for example, operates from 2 to 10 GHz with +10-dBm output power. The total output-power variation over temperature (–20 to +70°C) and frequency is 5 dB or less. The phase-locked synthesizer is capable of tuning in steps as small as 1 Hz. The switching speed for a 100-MHz step is 10 ms, and only 11 ms for a full 1-GHz frequency step. For a full-band frequency step, the MLSW-2010 requires only 18 ms.

The MLSW and MLSN frequency synthesizers combine excellent spectral purity with high-frequency resolution in a compact coaxial housing.

The spectral purity of the MLSW series should make them attractive for manufacturers of test equipment, such as signal generators and spectrum analyzers. The MLSW-2010, for example, achieves phase noise of –73 dBc/Hz offset 100 Hz from the carrier, dropping to –100 dBc/Hz offset 1 kHz from the carrier. Further from the carrier, the phase noise drops to –112 dBc/Hz offset 100 kHz from the carrier and –135 dBc/Hz offset 1 MHz from the carrier. For the lower-frequency (0.6-to-3.0-GHz) model MLSW-0603, the phase-noise performance is even better: –80 dBc/Hz offset 100 Hz from the carrier, –100 dBc/Hz offset 1 kHz from the car-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rier, –118 dBc/Hz offset 100 kHz from the carrier, and –140 dBc/Hz offset 1 MHz from the carrier. The nonharmonic spurious content for all three MLSW series synthesizers is –60 dBc.

Narrowband MLSN series synthesizers are suitable for telecommunications and SATCOM applications, with the spectral purity needed to support high-data-rate digital radios operating with 256-to-1024-state quadrature-amplitude-modulation (QAM) formats. Models are available for coverage of 2 to 4 GHz, 3 to 5 GHz, 4 to 6 GHz, and 5 to 7 GHz, with +10-dBm output power at the highest frequencies and +13-dBm output power from 2 to 4 GHz. The maximum output-power variations over frequency and temperature are 4 dB for the highest-frequency model (and 3 dB for the other models).

Similar to their wideband counterparts, the MLSN series synthesizers feature minimum tuning steps of 1 Hz and spurious content of –60 dBc. The narrowband synthesizers succeed in lowering the far-from-the-carrier single-sideband (SSB) phase noise even further than the MLSW series, reaching levels of –145 dBc/Hz offset 1 MHz from the carrier for the 2-to-4-GHz and 3-to-5-GHz models. For example, for the 2-to-4-GHz model MLSN-2040, the phase noise is –80 dBc/Hz offset 100 Hz from the carrier, –100 dBc/Hz offset 1 kHz from the carrier –120 dBc/Hz offset 100 kHz from the carrier, and –145 dBc/Hz offset 1 MHz from the carrier. For the highest-frequency member of the line, the 5-to-7-GHz model MLSN-5070, the phase noise is is –77 dBc/Hz offset 100 Hz from the carrier, –98 dBc/Hz offset 1 kHz from the carrier –116 dBc/Hz offset 100 kHz from the carrier, and –140 dBc/Hz offset 1 MHz from the carrier.

The MLSN series synthesizers typically require 10 ms to complete a 100-MHz tuning step, and 11 ms to tune across 1 GHz. To tune across the full bandwidth (2 GHz), the synthesizers require only 12 ms. Standard units are designed to work with a fixed 10-MHz external reference source. As an option, the synthesizers can be outfitted to work with external reference oscillators from 5 to 50 MHz. Both synthesizer series are programmed through a five-wire serial bus. All models feature a three-minute warmup time, and an option for a second LO frequency (from 500 to 2700 MHz for all models). The synthesizers measure 7 × 5 × 1 in. (17.78 × 12.70 × 2.54 cm). **Micro Lambda Wireless, Inc., 48041 Fremont Blvd., Fremont, CA 94538; (510) 770-9221, FAX: (510) 770-9213, Internet: www.microlambdawireless.com.**

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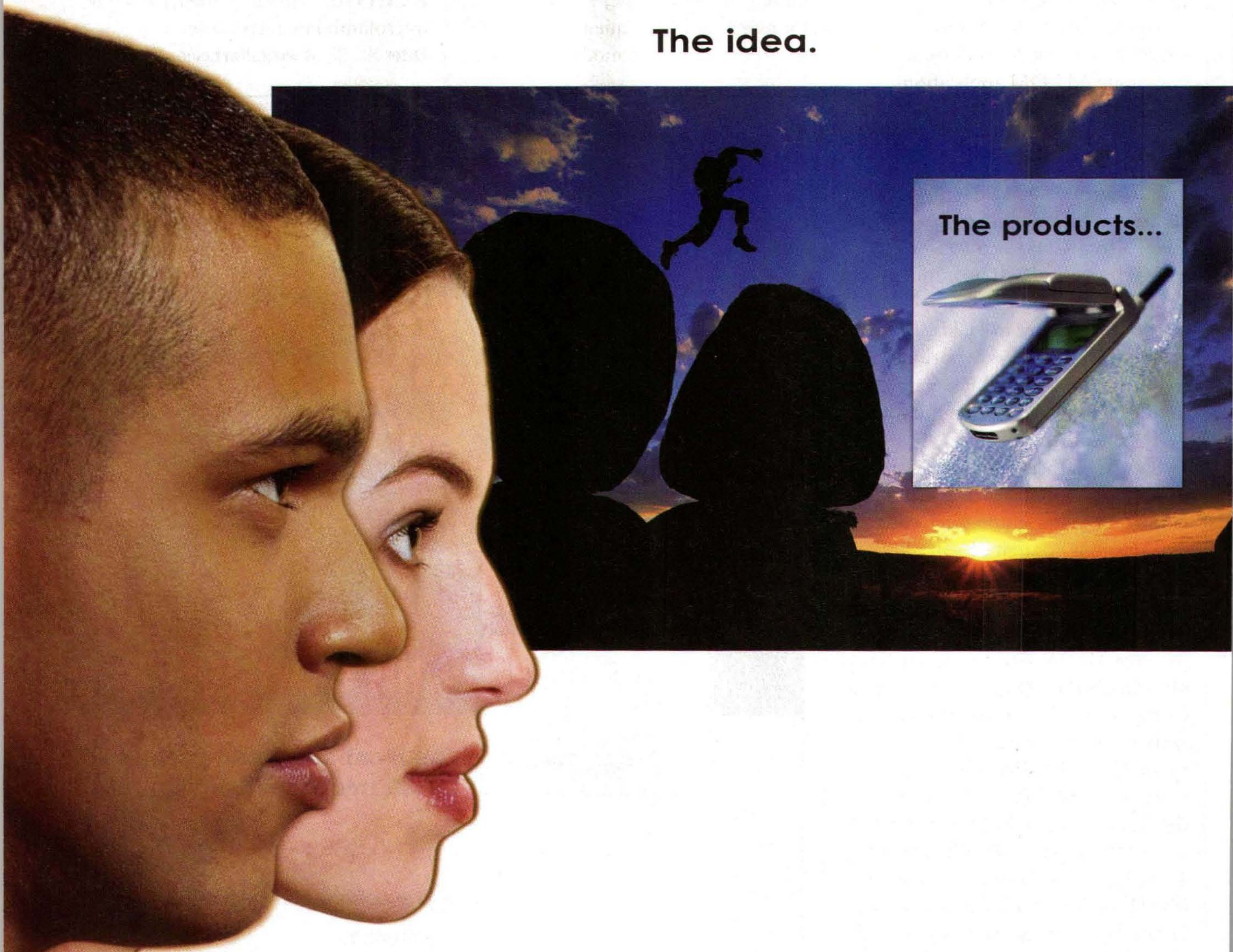
The idea.
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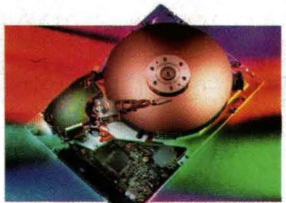


FBAR Duplexers Screen PCS Band

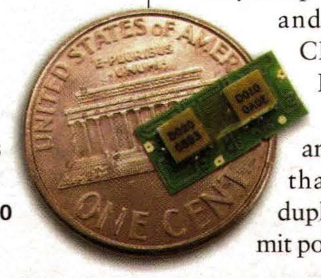
These miniature duplexers are designed for handset use at receive frequencies from 1930 to 1990 MHz and transmit frequencies from 1850 to 1910 MHz.

JACK BROWNE
Publisher/Editor

Size is everything in cellular handset design. When a designer can shrink a cellular handset printed-circuit board (PCB) even slightly, the handset manufacturer benefits with a highly marketable new form factor for customers seeking the ultimate in portability. The latest surface-mount duplexer filters from Agilent Technologies (Santa Clara, CA) provide that edge in small size, with a footprint of only 5.6 × 11.9 mm and a height of less than 2 mm. The models HPMD-7904 and HPMD-7905 duplexers are designed for handset and data-card applications at code-division-multiple-access (CDMA) receive frequencies from 1930 to 1990 MHz and transmit frequencies from 1850 to 1910 MHz.

The duplexers **(see figure)** are based on film-bulk-acoustic-resonator (FBAR) material, a technology that can be used to form high-quality-factor (Q) resonators in a fraction of the size of other resonator technologies. In fact, the models HPMD-7904 and HPMD-7905 duplexers are 50 to 80 percent smaller than competing duplexers.

These duplexers are designed basically to separate signals in the receive and transmit paths of a CDMA handset. The HPMD-7904 offers slightly better insertion-loss and isolation performance than the HPMD-7905 duplexer, with similar transmit power-handling capability of 1 W (+30 dBm).



The HPMD-7904 is a low-cost FBAR duplexer filter designed for PCS applications at receive frequencies of 1930 to 1990 MHz and transmit frequencies of 1850 to 1910 MHz.

The HPMD-7904 provides minimum 50-dB attenuation (typical 54 dB) of transmitted signals at the receiver (Rx) input and minimum 40-dB rejection (typical 42 dB) of transmit-generated noise in the receive band. Typical transmit-band insertion loss is only 1.8 dB, while typical receive-band loss is 2.2 dB, rising to 3.0 dB at the receive-band edges.

The HPMD-7905 offers minimum 48-dB attenuation of transmitted signals at the Rx input and minimum 37-dB rejection of transmit-generated noise in the receive band. Typical transmit-band loss is only 2.5 dB, while typical loss in the receive band is 3.0 dB.

With the sub-2-mm height, the HPMD-7904 and HPMD-7905 duplexers offer attractive alternatives to ceramic and other filter formats in cellular handsets, data cards, and personal digital assistants (PDAs). P&A: $3.80 (HPMD-7904) and $3.30 [HPMD-7905](1 million qty.); stock. **Agilent Technologies, Inc., 3175 Bowers Ave., Santa Clara, CA 95054; (800) 235-0312, FAX: (408) 654-8575, Internet: www.agilent.com/view/fbar.** MRF

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S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
S15W2	S15W5	N15W5	15	±0.60
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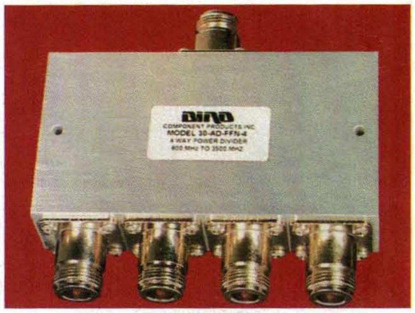
Divider/Combiner Works To 3.5 GHz



MODEL 30-AD-FFN-4 IS a four-way Wilkinson divider/combiner with a frequency range of 800 MHz to 3.5 GHz. Power rating is 30 W into a 1.15:1 VSWR, 10 W into 1.50:1, and 1 W into an open circuit. Insertion loss is less than 1.2 dB (above 6-dB split), while minimum isolation is greater than 25 dB, and VSWR is 1.2:1 maximum. Connectors are N female.

Bird Component Products, 10950 72nd St., Suite 107, Largo, FL 33777; (727) 547-8826, FAX: (727) 547-0806, e-mail: sales@birdfla.com, Internet: www.birdfla.com.

● **Enter NO. 64 at www.mwrf.com**

Epoxy Boasts 60-W/mK Thermal Conductivity

MODEL DM6030HK IS a silver (Ag)-loaded thermally and electrically conductive adhesive system. Using a unique, patent-pending organic system, high filler loading of Ag powders/flake combinations can be achieved. The epoxy provides a highly conductive polymer matrix when cured. Thermal conductivity is 60 W/mK and electrical resistivity is as low as 6 µΩcm. Shelf life is six months at room temperature with less than 25-percent viscosity increase and no loss in material functionality. Under frozen conditions, shelf life is one year minimum.

Diemat, Inc., 19 Central St., Byfield, MA 01922; (978) 499-0900, FAX: (978) 499-8484, Internet: www.diemat.com.

● **Enter NO. 65 at www.mwrf.com**

Modulator Driver Amplifiers Power OC-768 Systems

MODULATOR DRIVER AMPLIFIERS in the MDADC40 series are optimized to drive lithium niobate ($LiNb_3$) modulators in OC-768 40-Gb/s systems. The amplifiers are capable of high output voltages to +8 VDC peak to peak, and feature operating bandwidths of 25 kHz to 4 GHz. Models are available with gain leels of 10, 20, and 30 dB; an automatic-gain-control (AGC) level adjustment supports output-voltage amplitude variation for matching the voltage requirements of the modulator.

Sophia Wireless, Inc., 14225-C Sullyfield Circle, Chantilly, VA 20151; (703) 961-9573, FAX: (703) 961-9576, Internet: www.sophiawireless.com.

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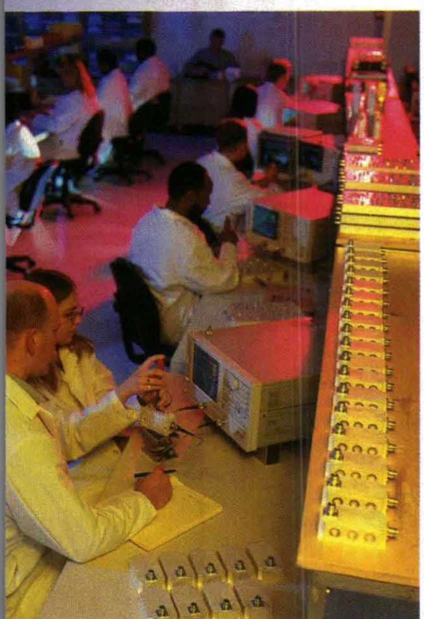
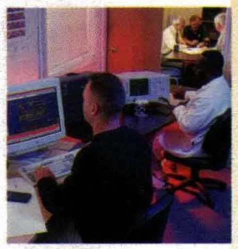
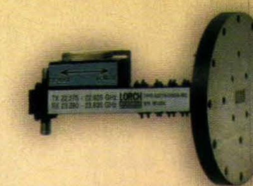
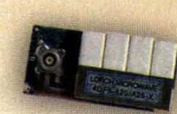
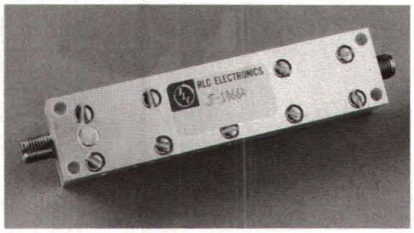








Filter Suppresses Spurious Signals



MODEL JF-500 IS a jitter filter designed to suppress the harmonic content of the reference clock and recovered clock signals in jitter-analysis systems, as well as to suppress any subharmonics or other spurious signals. With a center frequency of 500 MHz, the filter has a minimum 1-dB bandwidth of 496 to 504 MHz with a return loss of at least 18 dB. Rejection is at least 20 dB at 492 and 508 MHz and 30 dB at 488 and 512 MHz. The filter, which is rated for 0.5 W average power, operates at temperatures from +10 to +45°C. The impedance is 50 Ω and the VSWR is 1.3:1 over the specified 1-dB bandwidth.

RLC Electronics, Inc., 83 Radio Circle, Mt. Kisco, NY 10549; (914) 241-1334, FAX: (914) 241-1753, e-mail: sales@rlcelectronics.com, Internet: www.rlcelectronics.com.

● **Enter NO. 67 at www.mwrf.com**

Software Performs Real-Time Mapping

DOLPHIN™ IS A Windows® application for real-time mapping of Global Positioning System (GPS)-based wireless test instruments, including 802.11 wireless local-area-network (WLAN) receivers (Rxs). Dolphin tracks a drive-study path using any MapInfo®-compatible map and overlaying the received measurements for all of their correlating GPS positional data. Collected data include received signal-strength indicator (RSSI), E_c/I_o, and other user-defined measurements. All functions are executed using a Rx, MapInfo street maps, and a laptop with an RS-232 port in real time, while the user is still in the field. Dolphin software runs on any PC using Windows 95, 98, CE, 2000, or ME.

Berkeley Varitronics Systems, Inc., Liberty Corporate Park, 255 Liberty St., Metuchen, NJ 08840; (732) 548-3737, FAX: (732) 548-3404, e-mail: info@bvsystems.com, Internet: www.bvsystems.com.

● **Enter NO. 68 at www.mwrf.com**

PA Boasts +30-dBm P1dB Output Power

MODEL HMC408LP3 IS a 5.1-to-5.9-GHz gallium-arsenide (GaAs) heterojunction-bipolar-transistor (HBT) monolithic-microwave-integrated-circuit (MMIC) power amplifier (PA) with +30-dBm P1dB output power and +43-dBm output third-order intercept point (IP3). The PA is suitable for low-coast Unlicensed National Information Infrastructure (UNII) point-to-point/multipoint and 802.11a/HiperLAN wideband-local-area-network (WLAN) access-point applications. The PA provides 20 dB of gain and +32.5 dBm of saturated power at 27-percent power-added efficiency (PAE) from a single +5-VDC supply.

Hittite Microwave Corp., 12 Elizabeth Dr., Chelmsford, MA 01824; (978) 250-3343, FAX: (978) 250-3373, Internet: www.hittite.com.

● **Enter NO. 69 at www.mwrf.com**

Amplifier Provides 23-dB Gain

MODEL BP60070120 IS a high-intercept amplifier that operates in the frequency range of 20 to 2000 MHz. The unit provides 23-dB gain and 30-dBm output power at 1-dB gain compression. Third-order intercept point (IP3) is +41 dBm and second-order intercept point (IP2) is +65 dBm. Gain flatness is ±1 dB typical and input/output (I/O) VSWR is 2:1 maximum. Operating with a voltage of +15 VDC, the amplifier draws a nominal 550 mA. Noise figure is below 4 dB above 50 MHz and typically below 3 dB above 100 MHz.

AML Communications, Inc., 1000 Avenida Acaso, Camarillo, CA 93012; (805) 388-1345, Internet: www.amlj.com.

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Penton TECHNOLOGY MEDIA

looking back

ALMOST 16 YEARS AGO, RF engineers working at 3 GHz and below welcomed the availability of HP 8753A from Hewlett-Packard Co. (Palo Alto, CA), the industry's first vector network analyzer (VNA) designed for the RF, rather than the microwave, engineer.

next month

Microwaves & RF September Editorial Preview

Issue Theme: Communications

News

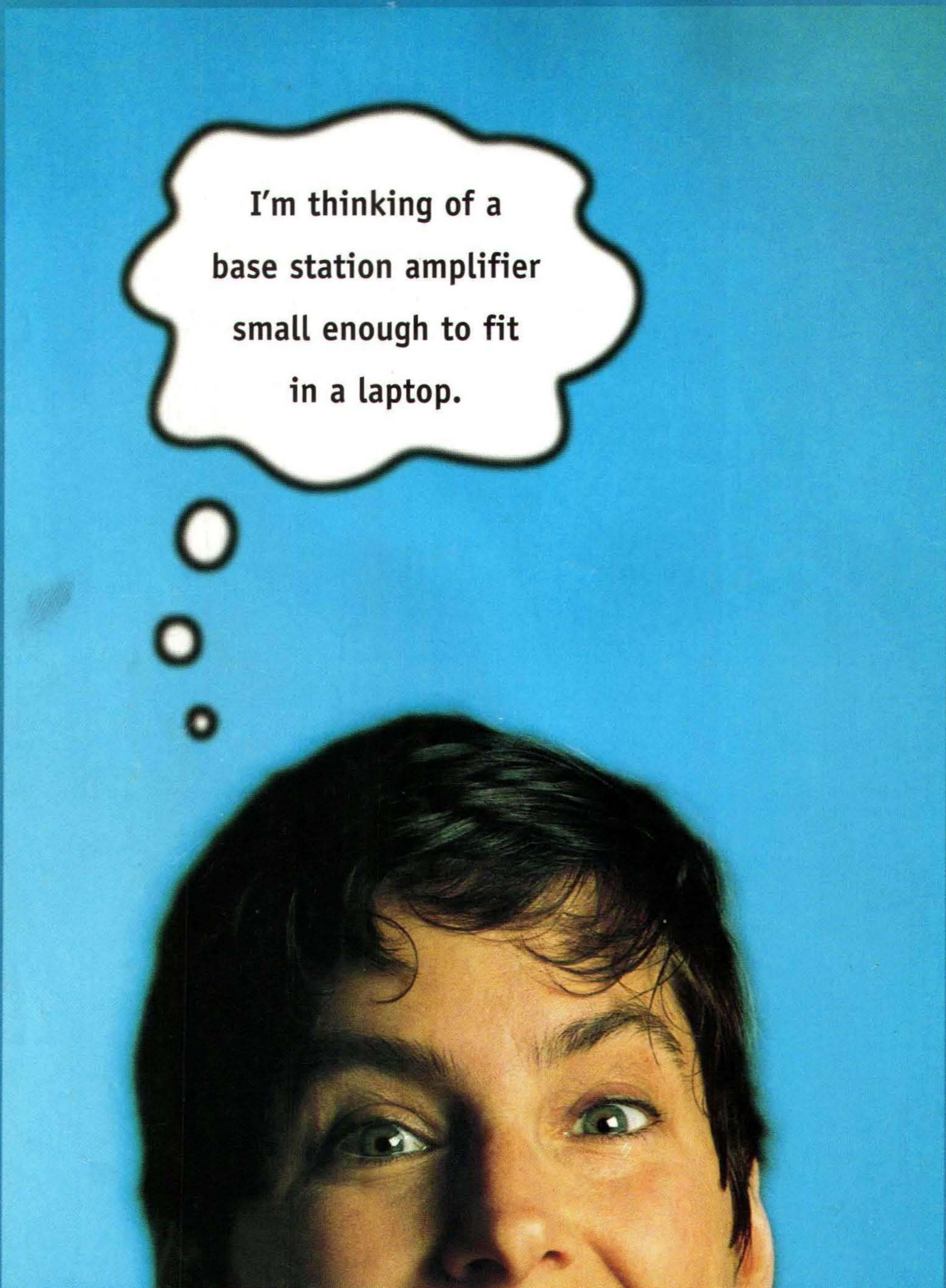
September will lead off with a preview of the second Military Electronics Show (MES). The MES (for more information, please visit the website at www.mes2002.com) is scheduled for September 24-25, 2002 in the Baltimore Convention Center (Baltimore, MD) and will feature technical sessions designed to help engineers working on military systems. These sessions provide detailed information and design guidance on all aspects of a military system, including antennas, power supplies and converters, components, computers and peripherals, CAE software, DSPs, Rxs, Txs, and test equipment. This preview will also highlight some of the latest product announcements expected from MES exhibitors, a list that includes Agilent Technologies, American Microwave, Ansoft, Noise Com, Northrop Grumman, Raytheon, and Tektronix.

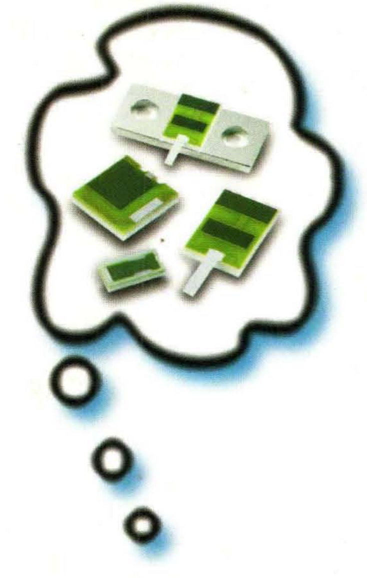
Design Features

One of the more interesting of modern communications formats is based on UWB technology. In a report from UWB leader XtremeSpectrum, the company's biphase modulation approach to UWB will be examined for its capability of transmitting high data rates at extremely low power levels. In addition, there has long been concern about the possible nonthermal effects of RF and microwave fields. In September, Dr. A. Kumar from AK Electromagnetique (Quebec, Canada) will examine the mechanisms of these nonthermal effects and provide direct evidence of DNA strand breakage. In other articles, authors from Analog Devices will describe the design of a single-chip direct-conversion Rx with an operating range of 800 to 2700 MHz, while researchers from Modelithics (Terrace, FL) will show the effects of frequency extrapolation errors during broadband computer-aided-engineering (CAE) simulations.

Product Technology

The September Product Technology will introduce a line of frequency synthesizers based on SAW tunable oscillators. The section will also highlight a bold new material for achieving high shielding effectiveness (SE) at low cost. Additional product features will showcase a wideband VNA system that works with modulated test signals, highlight a new supplier of LTCC circuit technology, explore the use of a specialized ASIC in high-performance TCXOs, and introduce a family of SiGe-based devices for GPS applications.





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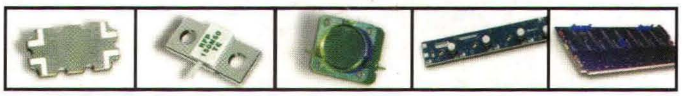

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